PB188619

SURVEY OF THE USE OF RADIONUCLIDES IN MEDICINE

Prepared for:

BUREAU OF RADIOLOGICAL HEALTH
U.S. PUBLIC HEALTH SERVICE
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

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August 1969

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CONTRACT PH 86-67-15

SRI Project MU 6219

Supersedes PB 182 888

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ACKNOWLEDGMENTS

Valuable assistance and guidance were provided by William G. Madow in applying statistical concepts to formulate the approach and evaluate the results of this study. Gertrude D. Peterson assisted greatly in the difficult task of designing survey questionnaires that were effective research tools.

SUMMARY

Phase I

The Phase I study, which was a national survey of all licensed and registered medical users of radionuclides, required the compilation of a comprehensive registry of physicians using radionuclides for medical purposes, and the development of a survey questionnaire.

Data from the medical licensing records of the Atomic Energy Commission and the states that have assumed licensing authority by agreement with the AEC were merged into an alphabetical file by name of licensee. To these were added data from those nonagreement states that require registry of medical users of radionuclides. A final registry of 7,204 names was obtained.

The survey questionnaire was designed to determine a physician's usage of radionuclides in diagnostic, therapeutic, and research procedures in 1966. The diagnostic procedures included function studies (in vitro and in vivo), and scanning studies. The therapeutic procedures included radiopharmaceutical therapy, brachytherapy, and teletherapy.

After a trial test of the questionnaire, it was sent to all of the physicians in the registry, 40 percent of whom responded. Twenty-four percent responded to a second submission of the questionnaire to the nonrespondents for a combined response of 54 percent. The number of these respondents actually using radionuclides in medicine in 1966 was 2,510 (65 percent of the 3,856 respondents).

In all, five followup surveys of the nonresponding population were made in this study. The first followup survey was simply a resubmission of the original questionnaire to all nonrespondents, but the other four were more specialized. Followup surveys two through four were conducted to determine the number of radionuclide users in the physicians who had not responded to the original questionnaire. The fifth followup survey

determined the radionuclide usage of this population in terms of procedures, patients, and administrations. These surveys determined that there were approximately 1,491 physicians using radionuclides who did not respond to the original questionnaire. The overall response was increased to 85 percent by the followup surveys.

The radionuclide usage characteristics of this nonresponding population were generally comparable with those who responded to the original and first followup survey, but there was some indication that the practitioners in the fifth followup survey had more patients for brachytherapy and teletherapy.

Of the 4,001 physicians using radionuclides in 1966, 2,742 (68.5 percent) were classified as primarily performing diagnostic studies, 1,014 (25.4 percent) as primarily performing therapeutic studies, and 245 (6.1 percent) as having an equally mixed practice. The annual patient loads of 40.5 percent of these physicians was between 100 and 999. Nine physicians each reported more than 10,000 patients a year; however, eight of them had performed large numbers of a particular in vitro procedure. There were few respondents who were engaged primarily in research.

Three nuclear medical procedures were reported as being routinely performed in vitro. The number of thyroid function tests using triodothyronine (T-3) performed in 1966 exceeded the total of all other radionuclide function studies, even though many practitioners in clinical laboratories were not included in the survey since an AEC license is not required.

The number of administrations of ^{131}I for thyroid uptake studies represented more than one half of the total for 50 different function studies reported, which was projected to be about 860,000 administrations. Radioactive iodine was used in more than 85 percent of the total number of administrations for function studies. The second most widely used radionuclide in function studies was ^{57}Co for vitamin B-12 absorption tests. It was used with a 23 percent greater frequency than the long half-life ^{60}Co. Blood volume determination was the second most widely performed function study. It was usually conducted with radioiodinated human serum albumin.

The most widely employed scanning procedure was thyroid scanning. Brain scanning was the second most utilized, followed by liver and kidney scanning. Four different radionuclides were reported for brain scanning. However, ^{99m}Tc had surpassed the number of administrations of all other radionuclides used in brain scanning in the two years since its introduction in 1964. Three commonly used liver scanning agents were reported. Colloid ^{198}Au and ^{131}I-labeled rose bengal were used for more than 95 percent of the administrations; however, ^{99m}Tc-labeled sulfur colloid had significant use.

The number of patient administrations of radioiodine for treatment of hyperthyroidism represented 69.3 percent of the number of projected therapeutic administrations of radiopharmaceuticals. Radium was the most widely used radionuclide for brachytherapy and its primary use was for the intracavitary treatment of cancer. Some 3-1/3 million teletherapy administrations were given during 1966. Cancer was the only condition reported treated and over 90 percent of the treatments were made with ^{60}Co teletherapy units.

A great variety of research studies was reported, and 67 percent of them used one of four radionuclides; ^{131}I, ^{125}I, ^{14}C, and ^{3}H.

The results of the followup surveys were used to project the radionuclide usage of the total population of physicians practicing nuclear medicine in 1966. This projection indicated that approximately 1,575,000 radiopharmaceutical administrations were made during the year 1966. This compares with a study conducted by SRI for the AEC, which estimated that a total of 400,000 doses of radiopharmaceuticals were administered to humans during the year 1959, exclusive of teletherapy and brachytherapy. Accordingly the number of radiopharmaceutical administrations per year has increased approximately fourfold during that 9-year interval.

Phase II

In the Phase II study, the practice of diagnostic nuclear medicine was described with particular emphasis on those measures that minimize patient radiation exposure. A statistical approach using a sampling of practitioners as the data source was employed. A survey questionnaire was designed to obtain data on radiopharmaceutical handling, patient safeguards, and instrument calibration practices. A pretesting of this questionnaire with a limited number of respondents indicated that only slight modifications were required.

The Phase II sample population was selected from a sector of the Phase I respondents who reported doing one or more of some 23 radiopharmaceutical procedures in 1966. These 23 procedures accounted for over 95 percent of the total number of patients reported in Phase I as receiving radiopharmaceuticals for diagnostic purposes. The physician sampling plan was designed to make the probability of being sampled for a procedure depend on the number of patients for that procedure. Within the limits imposed by the necessity of obtaining a sufficiently large sample for each procedure, the number of procedures for which any physician was asked to respond, as well as the number of physicians receiving questionnaires on two or more procedures using the same radionuclide, were minimized.

A total of 1,082 survey questionnaires was mailed to 879 selected physicians in early 1969. After about five weeks a second mailing was made to all physicians who had not yet responded. The overall response was 85.2 percent of the physicians with 85.4 percent of the questionnaires. In 21.6 percent of the responses the physician indicated that he had changed radionuclides for the procedure and in 12.9 percent, that he was no longer doing the particular procedure. Since the procedures sampled were based on their use in 1966, a change in radionuclides of this extent in a three-year period indicates the fast pace of technical development in the practice of nuclear medicine. Where changes in radionuclides were indicated, the data were included in the analysis of the corresponding procedure if the procedure with the changed radionuclide was the same as another of the 23 procedures originally sampled. All but 22 of the reported 195 radionuclide changes did correspond to one of the original 23 sampled procedures.

Because of changes in procedure resulting from radionuclide changes, the sample size of complete data for detailed analysis was quite small for some procedures. The rules adopted for determining if sufficient data were available for detailed analysis of a procedure resulted in insufficient response for four procedures and only "yes or no" type answers for two other procedures were included in the analyses.

The results indicate that at least 75 percent of physicians who perform any of the 23 specified procedures do so in hospitals. The only procedures employed by a significant fraction of the physicians (more than 10 percent) not engaged in hospital practice, i.e., private or group practice, include thyroid uptake and scanning, the two vitamin B-12 malabsorption procedures, the two most widely used liver scanning procedures, and the most widely used kidney scanning procedure.

The only radionuclide that a majority of the physicians procure in the form of a generator is ^{99m}Tc. More than half of the physicians procure unit doses of radiopharmaceuticals for the vitamin B-12 malabsorption, the $^{125/131}$I fat malabsorption, the ^{131}I iodide thyroid uptake and scanning, and the $^{125/131}$I human serum albumin blood volume and placental location procedures. The majority of the physicians performing the remaining procedures under consideration procure the radiopharmaceutical in the form of multi-dose lots.

In all but three procedures at least 50 percent of the practitioners appear to rely on the suppliers for quality control of the as-received radiopharmaceutical. These three procedures use radionuclides that a majority of the practitioners procure as generator-produced material. Those practitioners who do conduct testing on the as-received material usually conduct an activity assay. In general, a larger fraction of the physicians who procure a radionuclide in multi-dose lots conduct quality assurance tests than those who procure it in unit doses.

In all of the scanning procedures except liver scanning with sulfur colloid tagged with ^{99m}Tc, more than 75 percent of the physicians reported no radiopharmaceutical modification. Tagging was also indicated as the modification performed by about a third of the physicians performing placental localization with red blood cells tagged with ^{51}Cr. Most of the other physicians conducting modifications performed sample dilutions. The majority of the physicians who used modified radiopharmaceuticals conducted some testing before administration, and almost all the physicians who performed tests conduct at least an activity assay.

More than two-thirds of the practitioners of three of the procedures using radioiodine-tagged materials reported that they administered iodide blocking agents to prevent the accumulation of radioiodine in the thyroid.

Although the range of values of average administered activity was wide for most procedures, the average value (which is weighted to represent all physicians performing a procedure) compared favorably with the values reported in well-known references.

The practice of administering agents to accelerate the elimination of radionuclide from the patient is not widespread. It was reported as being used by more than one-fourth of the practitioners of only two procedures, and these are procedures that use accelerated elimination to improve diagnostic effectiveness.

Almost all of the practitioners calibrate their radiation detection and measuring instruments with some frequency. Generally speaking, the majority calibrate with each use or at least daily. The fraction of those who calibrate at increasing intervals decreases with the length of the interval.

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PHASE I

SURVEY OF MEDICAL USERS OF RADIONUCLIDES

I APPROACH

Any survey requires the specification of the population to be studied and a method for obtaining the desired information from that population. The approach taken to describe the medical use of radionuclides in the United States was to question those who use radionuclides in the treatment of human patients concerning their usage of radionuclides over a particular time period. Accordingly, it was necessary to compile a national list of all users and then to submit a questionnaire to each of them requesting data on their usage of radionuclides.

Survey Population

The first task of the survey was to compile a registry of names and addresses of all physicians in the United States who were licensed or registered to administer radionuclides to human beings. This information was compiled from several sources.

All users of byproduct radionuclide materials, which are those produced in nuclear reactors, must be licensed by the U.S. Atomic Energy Commission or by an Agreement State.

Licenses may be issued to institutions or to private practitioners Under some types of licenses, nonapproved physicians under the supervision of the physicians named on the license may obtain basic and clinical radionuclide training and experience that may enable them to qualify as individual users. The various types of AEC licenses and their characteristics are given below.* The licenses issued by the Agreement States generally correspond to these categories.

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* "A Guide for the Preparation of Applications for the Medical Use of Radioisotopes," Division of Materials Licensing, U.S. Atomic Energy Commission, Washington, D.C., 20545, November 1965.

- Specific licenses issued to institutions--specify the radionuclides and the clinical uses that can be performed by physicians named on the license. Regulations require that an institutional licensee have a medical isotope committee to evaluate all proposals for clinical research, diagnostic, and therapeutic uses of radionuclides within the institution. Institutional licenses provide a means whereby nonapproved physicians may obtain basic and clinical radionuclide training and experience under the supervision of physicians named on the license.

- Broad medical licenses issued to institutions--authorize multiple quantities and types of byproduct material for unspecified uses and are issued to institutions that (1) have had previous experience operating under a specific institutional license and (2) are engaged in medical research, as well as routine diagnosis and therapy, using radioisotopes. Such programs operate under the supervision of a medical isotopes committee. Physicians may obtain basic and clinical radionuclide training and experience in the use of radiopharmaceuticals in such programs.

- Specific licenses issued to physicians for their private practice--specify the types of radionuclides and the clinical uses to which they may be applied by the physician with the license. These licenses are limited to well established uses of byproduct materials and require that the physician so licensed personally conduct the program.

- General licenses for certain diagnostic uses--authorizes the registrant physician to possess and use limited quantities of prepackaged individual doses of: ^{131}I for measurement of thyroid uptake; ^{125}I and ^{131}I for blood and plasma volume determinations; ^{60}Co and ^{58}Co for intestinal absorption of cyanocobalamin; and ^{51}Cr for red blood cell volume and survival time determinations.

- Specific licenses for the teletherapy use of radionuclides.

The specific licenses for both institutions and individual physicians specify groups of diagnostic procedures that may be performed by the physicians named on the license. Group I includes well established uptake, dilution, and excretion studies while Group II includes scans and tumor localization procedures. Groups III and IV include various therapeutic procedures.

Only certain states require physicians using naturally occurring radionuclides, such as radium or accelerator-produced radionuclides, to be registered.

As of September 30, 1966, the AEC and Agreement State licensing programs reported 5,028 "byproduct material" licenses for medical use.* An estimate of 2,000 medical radium users was reported by State and local radiological health programs as of July 1966.† A registry listing physicians licensed or registered to administer radioisotopes to human beings was prepared from these various sources of data.

A copy of the AEC records was obtained during August 1966 and was brought up to date by including new licenses that had not been incorporated. The names of the staff members who administer radionuclides under institutional or broad licenses were provided by the chairman of the committee on human use of radionuclides at each facility. Each director of the State Radiological Health Program in Agreement States provided the names and addresses of the individuals and institutions possessing licenses in his state All but one of the nonagreement states where registry was required provided names and addresses of individuals and institutions using radium and other naturally occurring radioisotopes, and accelerator-produced radionuclides on humans; however registry was not required in 18 states.

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* U.S. Atomic Energy Commission. Division of State and Licensee Relations Exchange of Information Calendar for the period ending September 30, 1966 (For Official Use Only).

† Dept. HEW, Public Health Service, National Center for Radiological Health. Report of State and local radiological health programs for fiscal year 1966, Report No. CCB67-2. Superintendant of Documents, U.S. Government Printing Office, Washington, D.C., 20402 (July 1967).

All of the data were merged and edited. Computerized data processing methods were used to eliminate duplicate entries, which resulted from overlaps in the license records and from the fact that several physicians administered radionuclides under more than one license. The final registry contained the names and addresses of 7,204 physicians and constituted the survey population for the Phase I study. It should be emphasized that those physicians using radionuclides in their practice without being required to hold a license or to be registered are not included.

Survey Questionnaire

Clinical procedures using radionuclides may generally be classified as nuclear medicine, brachytherapy, and teletherapy. These classifications may be defined as follows:

- "Nuclear medicine is the scientific and clinical discipline concerned with the diagnostic, therapeutic (exclusive of sealed radiation sources), and investigative use of radionuclides."*

- Brachytherapy (therapy at short distances) is the treatment of disease with sealed radioactive sources placed near, or inserted directly into the diseased area.

- Teletherapy (therapy at long distances) is the treatment of disease with gamma radiations from a source located at a defined distance from the patient.

The subject matter for the study was organized into two main categories: diagnostic and therapeutic. The sections under diagnostic procedures are:

- Function studies--"routine" patient counting and sample counting.

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* M. A. Bender, J. Nucl. Med., 8, 901 (December 1967).

- Scanning studies--pictorial representations of radionuclide distribution.

- Research studies--"nonroutine" investigative studies.

These diagnostic studies are included in the field of nuclear medicine as defined above. Radiopharmaceutical therapy is also part of nuclear medicine but, for convenience, it was grouped with the other therapy procedures for consideration in this study. The sections under therapeutic procedures are:

- Radiopharmaceutical therapy--procedures for internal administration using only radiopharmaceuticals.

- Brachytherapy--use of sealed or encapsulated sources for interstitial, superficial, or intracavitary procedures.

- Teletherapy--^{60}Co or ^{137}Cs beam therapy.

- Therapy research--"nonroutine" investigative procedures.

A survey questionnaire was designed to obtain quantitative data on the medical use of radionuclides during a given period of time. The questionnaire is shown in Appendix A. It contains a listing of the more common procedures, divided into diagnostic and therapeutic categories. Three check-off blocks are provided for each procedure. By checking the appropriate blocks the physician indicates if he is licensed to perform the procedure, if he has ever used the procedure, and if he has not used it in the past year. In the spaces following each procedure the physician can enter the number of patients he treated and the administrations for the year. Information on procedures not listed can be entered on blank spaces provided in several places. The physician can also make additions or corrections to the list of his licenses and places of practice in the space provided.

The survey questionnaire was pretested to determine its effectiveness. Questionnaires were sent to 50 physicians selected at random from the registry who were asked to complete the questionnaire and to comment on its format. On the basis of the results, the questionnaire was revised and sent to another 50 physicians. Their comments indicated that the revised questionnaire was satisfactory. The overall response to the pretesting program was 50 percent.

Questionnaires had been sent to 7,204 physicians in the United States by the end of January 1967. At the end of March replies had been received from 2,876 physicians for a 40 percent response. The same questionnaire was again sent to all physicians who had not responded; and by the end of June 1967, a total of 3,856 physicians had replied, for an overall response of 54 percent.

Tabulation of Responses

To facilitate tabulation by data processing machines, the questionnaires completed by the physicians were coded when received. An identification number for the physician was assigned to his questionnaire. The responses for each procedure, diagnostic and therapeutic, were coded into categories corresponding to the sections under which they appeared on the questionnaire, e.g., function study = F, scanning study = S, and so forth. They were subcoded numerically within these categories according to the type of procedure. Write-ins on procedures not listed, particularly of research procedures, were difficult to code since some of the procedures used in research were unfamiliar. However, a cumulative record of code numbers assigned was maintained and procedures that were the same, even though referenced by different names, were eventually reconciled and consolidated under one code number.

II RESULTS

Classification by Type of Practice

The results obtained from the responding population can be classified in terms of the general type of response. Then those physicians whose response indicated that they used radionuclides in their practice can be further classified in terms of the type of practice and the numbers of patients. The types of response obtained from the 3,856 respondents are shown in Table 1.

Table 1. Type of response to survey questionnaire

Classification of respondent	Number	Percent
Physicians actively using radionuclides	2,510	65.1
Physicians not actively using radionuclides	691	17.9
Physicians included in another response	416	10.8
Nonpractitioners	165	4.3
Retired physicians	35	0.9
Deceased (answered by another physician)	31	0.8
Refusals to answer questionnaire	8	0.2
Total	3,856	100.0

Physicians Actively Using Radionuclides

The 2,510 responding physicians actively using radionuclides were classified as primarily performing diagnostic studies, therapeutic studies, or both. Within each general category there are subcategories of practice types. The physicians within each category and subcategory of practice type were grouped according to the total number of patients treated in the year. The groupings were according to orders of magnitude of the numbers of patients. Accordingly, a physician who treated several hundred patients was grouped in the 100-999 patient category, while the physician who treated several thousand patients was grouped in the 1,000-9,999 category. This classification by type of practice and number of patients is contained in Table 2.

The method for classifying a physician in a particular category by type of practice was to compare the numbers of patients he treated in the various categories. If he reported performing only diagnostic or only therapeutic studies he was assigned accordingly. If he performed diagnostic procedures and therapeutic procedures in approximately equal numbers, his practice was classified as "mixed diagnostic and therapeutic." If the number of patients in one category was at least twice the number in any other category, the practice was classified according to the major category. The same method was used in classifying the type of practice according to the subcategories under the diagnostic or therapeutic studies categories.

Of those physicians actively using radionuclides, 1,713 were classified as primarily performing diagnostic studies, 678 were classified as primarily performing therapeutic studies, while 119 had mixed diagnostic and therapeutic practices. Approximately half of the physicians with a diagnostic or mixed diagnostic and therapeutic practice treated 100-999 patients, while the physicians with therapeutic practices tended to have fewer patients. However, this category was strongly influenced by the small numbers of patients treated by the physicians engaged in brachytherapy. Over 90 percent of these physicians had less than 100 patients per year. Overall, 42 percent of the physicians actively using radionuclides had 100-999 patients per year.

Nine physicians each reported treating more than 10,000 patients a year. Eight of these physicians had performed large numbers of in vitro triiodothyronine (T-3) binding procedures with ^{125}I or ^{131}I.

Table 2. Classification of physicians by primary practice and patient load

Primary type of practice	Responding physicians							
	Total number of patients per year					Total	Percent	
	Under 10	10 to 99	100 to 999	1,000 to 9,999	Over 10,000		Subcategory	Category
Diagnostic studies								
Function	28	259	587	272	8	1,154	67.4	
Scanning	15	10	47	15	0	87	5.0	
Mixed function and scanning	1	23	163	169	0	356	20.8	
Research	39	57	19	1	0	116	6.8	
Total diagnostic	83	349	816	457	8	1,713	100.0	68.2
Therapeutic studies								
Radiopharmaceutical therapy	34	22	1	0	0	57	8.4	
Brachytherapy	192	193	25	1	0	411	60.6	
Teletherapy	1	19	140	19	1	180	26.5	
Mixed therapy	3	10	11	0	0	24	3.5	
Research	3	2	1	0	0	6	1.0	
Total therapeutic	233	246	178	20	1	678	100.0	27.0
Mixed diagnostic and therapeutic studies	5	36	61	17	0	119	100.0	4.8
Total users reporting	321	631	1,055	494	9	2,510		100.0
Percent	12.8	25.1	42.0	19.7	0.4	100.0		

Four of these nine physicians were practicing in large general hospitals, and with the assistance of other physicians were performing many diagnostic and therapeutic procedures. Three physicians worked in clinical laboratories in which the T-3 test was the only major procedure reported. One respondent, working in a clinic, reported thyroid function, scanning, and therapy procedures. The remaining physician, also working in a clinic, reported ^{60}Co teletherapy as his primary procedure.

Only a small number of respondents was classified as engaged primarily in research activities. Also, many researchers who did not respond for themselves were included in another's response and therefore could not be identified and classified in the category of primary research practice.

Physicians Included in Another Response

Usually one response was received for a group practice of physicians. Therefore, no estimate could be made for the practices of the individuals in the group. Accordingly, the procedures performed by all the members of the group were included and tabulated as part of the procedures attributed to the respondent. All physicians who reported that their procedures were included in another physician's response, or who did not respond but were reported as included by another responder, were classified as "physicians included in another response" in Table 1.

Physicians Not Actively Using Radionuclides

Eighteen percent of the respondents reported that they had not used radionuclides during 1966. Those who had not started practice or had retired are not included in this category. There is insufficient information available from the survey to classify these physicians according to their type of practice when they do use radionuclides. Since a large percentage of physicians who practice primarily brachytherapy reported very small numbers of patients, it is possible that a large proportion of these responding nonusers possess radium and have at some time in the past practiced brachytherapy.

Nonpractitioners

A substantial number of nonphysicians are listed in AEC files in medical or quasi-medical categories. For instance, radiation safety officers who perform calibration and safety work in medical centers and are custodians of radioactive materials must be licensed by the AEC, as well as the physicians who use these materials in the practice of nuclear medicine. Physicians or veterinarians who use radioactive materials in research on animals or on tissues in medical centers must have a valid AEC license. None of these licensees is a "medical user of radionuclides on humans" within the meaning of that term in this study. Such licensees, who constituted 165 of the 3,856 total respondents, were accordingly classified as nonpractitioners.

Classification by Type of Procedure

In this section the results obtained from the survey questionnaire are classified according to the various procedures. The numbers of physicians licensed for each procedure, those using the procedure for which they are licensed and the number of administrations that were reported for the various procedures are tabulated. It is again noted that the quantitative data presented relate only to respondents.

Nuclear Medicine

In vitro Procedures. The in vitro procedures do not require the administration of radioactive materials to the patient. The results of the survey, which are shown in Table 3, indicate that there were three in vitro nuclear medical procedures performed by physicians in 1966. These tests are available to all doctors, hospitals, and clinical laboratories without the need for an AEC license. Since only those physicians having an AEC or Agreement State license are included in the survey, the number of such tests reported in this survey is considerably lower than the actual number.

The most frequently used in vitro procedure is the thyroid function test using triiodothyronine (T-3). The number of T-3 tests performed in 1966 by those physicians reporting exceeds the total number of all other radionuclide function studies performed. Other tests using

Table 3. Principal nuclear medical *in vitro* procedures performed during 1966

Radionuclide	Compound	Procedure	Physicians licensed for procedure	Physicians performing procedure	Patients	
					Number	Percent
^{131}I *	Triiodothyronine	T-3 binding	1,380	1,066	582,807	99.6
^{131}I	Thyroxine	T-4 resin uptake	3	2	1,124	0.2
^{59}Fe	Resin sponge	Iron binding	15	13	1,261	0.2
Total for *in vitro* procedures --					585,172	100.0

*Procedure using either ^{131}I or ^{125}I.

in vitro techniques are being developed.* Where the in vitro test replaces an in vivo procedure, the use of such tests can be a major factor in minimizing radiation exposure to patients.

Function Procedures. Data on the usage of the principal nuclear medicine function studies performed during 1966 are given in Table 4. Some 50 different function study procedures were reported in 1966, and the number of administrations of ^{131}I for thyroid uptake studies represents more than one-half of the total administrations. The use of ^{131}I for thyroid studies is a consequence of the unique position of iodine in thyroid physiology. This procedure was one of the first performed in clinical nuclear medicine, and it has been widely practiced ever since. Because it is suitable for tagging other pharmaceutical compounds, ^{131}I is also employed in five other popular function procedures with the result that it is used in more than 85 percent of all administrations for function studies.

The second most widely used radionuclide for function studies is ^{57}Co, for vitamin B-12 absorption tests. It was reported used with a 50 percent greater frequency than ^{60}Co. The ^{57}Co isotope form is preferable because of its short half-life and greater counting efficiency with most detectors. In the 1959 study on radioisotopes in medicine conducted by SRI,† ^{57}Co was not reported and ^{60}Co was the major isotope for vitamin B-12 studies. The change to ^{57}Co by the practitioners of this procedure demonstrates the advancing state of the art of nuclear medicine in a direction that minimizes the radiation exposure to the patient and at the same time provides improved diagnostic effectiveness.

The function study second most widely used is blood volume determination. The accurate measurement of the circulating blood volume is often an important factor in the successful management of a surgical patient. The blood volume determination is most often performed with ^{131}I labeled albumin, which provides a measure of plasma volume, although ^{51}Cr sodium chromate is used in approximately one-sixth of the

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* "Radioisotopes in Medicine: In Vitro Studies," U.S. Atomic Energy Commission, CONF-671111, June 1968.

† R. Tarrice and M. S. Blumberg, "Radioisotopes in Medicine," AEC Research and Development Report, December 1959.

Table 4. Principal nuclear medical function procedures performed during 1966

Radionuclide	Compound	Procedure	Physicians licensed for procedure	Physicians performing procedure	Patient administrations	
					Number	Percent
^{131}I	Sodium iodide	Thyroid uptake	1,527	1,284	301,052	57.2
^{131}I*	Labeled albumin	Blood volume determination	1,381	908	101,994	19.4
^{131}I*	Sodium iodohippurate	Renal function	817	388	33,245	6.3
^{57}Co	Labeled vitamin B_{12}	Vitamin B_{12} absorption	952	582	24,996	4.7
^{51}Cr	Sodium chromate	Blood volume determination	1,064	437	22,468	4.3
^{60}Co	Labeled vitamin B_{12}	Vitamin B_{12} absorption	1,149	556	16,486	3.1
^{131}I*	Labeled fats	Fat malabsorption	1,054	505	7,742	1.5
^{51}Cr	Sodium chromate	RBC survival	1,110	604	6,530	1.2
^{59}Fe	Chloride or citrate	Iron turnover	836	287	3,139	0.6
^{131}I*	Labeled albumin	Cardiac output	627	79	1,503	0.3
^{131}I*	Rose bengal	Hepatic function	33	23	1,202	0.2
Total for principal procedures listed above					520,357	98.8
Total for 39 other procedures with less than 1,000 administrations (Appendix B)					6,119	1.2
Total for all function procedures					526,476	100.0

* Administrations using either ^{131}I or ^{125}I.

studies. The procedure using ^{51}Cr measures red blood cell volume. The emergence of blood volume determination as a significant clinical tool is illustrated by its more than threefold increase in use since 1959 compared with a less than doubling in frequency of thyroid uptake studies.*

Scanning Procedures. Scanning procedures depend on a differential concentration of radionuclide in a given body organ. The concentration of radioiodine in thyroid tissue was used in the early development of procedures for visualizing the thyroid gland, as an aid in diagnosing and managing thyroid diseases. As indicated in the data of Table 5, thyroid scanning was the most widely used scanning procedure in 1966. The techniques developed in thyroid scanning have been extended to use for other organs, with the discovery of new radioactive tracer agents and the improvement of instrumentation. The relative frequency of scanning procedures by organ have been determined from the data reported in Table 5 and is shown in Table 6.

A comparison of the relative frequencies of the different brain scanning procedures illustrate some of the factors resulting in the use of a specific radionuclide. Four different radionuclides were reported for brain scanning. Radioiodinated human serum albumin (^{131}I) was at one time the most widely used substance. An improved radioactive scanning agent ^{203}Hg labeled chlormerodrin, was rapidly accepted as a clinically useful agent after its introduction in 1960. Because of the relatively high radiation dose to the kidney from ^{203}Hg, which results from the concentration of ionic mercury in the kidney, chlormerodrin labeled with the short half-life ^{197}Hg was prepared. The invariable contamination of the material with ^{203}Hg, together with the short half-life, detract from its usefulness with respect to both patient radiation dose and to the quality of the scan. In 1964 ^{99m}Tc was introduced for brain scanning as the pertechnetate ion. As the survey results indicate in the two-year period since its introduction ^{99m}Tc has surpassed in the number of administrations all other radionuclides employed in brain scanning. Its frequency of use in 1966 is ample confirmation of its

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* R. Tarrice and M. S. Blumberg, op cit.

Table 5. Principal nuclear medical scanning procedures performed during 1966

Radionuclide	Compound	Procedure	Physicians licensed for procedure	Physicians performing procedure	Patient administrations	
					Number	Percent
^{131}I	Sodium iodide	Thyroid scanning	1,092	908	153,089	37.4
^{99m}Tc	Pertechnetate	Brain scanning	528	330	63,078	15.4
^{198}Au	Colloidal gold	Liver scanning	730	539	41,855	10.2
^{203}Hg	Labeled mercurials	Brain scanning	329	320	37,746	9.2
^{131}I	Labeled albumin (MAA)	Lung scanning	757	562	22,840	5.6
^{131}I	Rose bengal	Liver scanning	823	503	19,721	4.8
^{197}Hg	Labeled mercurials	Brain scanning	162	145	18,489	4.5
^{203}Hg	Labeled mercurials	Kidney scanning	787	543	16,223	4.0
^{197}Hg	Labeled mercurials	Kidney scanning	646	282	6,972	1.7
^{85}Sr	Nitrate or chloride	Bone scanning	582	398	6,232	1.5
^{99m}Tc	Technetium sulfur colloid	Liver scanning	202	55	4,911	1.2
^{131}I*	Labeled albumin	Placenta scanning	619	325	3,921	1.0
^{131}I	Labeled albumin	Brain scanning	37	34	3,511	0.9
^{131}I	Sodium iodohippurate	Kidney scanning	483	99	2,091	0.5
^{75}Se	Selenomethionine	Pancreas scanning	263	121	1,635	0.4
^{51}Cr	Heat-treated RBC	Spleen scanning	554	287	1,628	0.4
^{125}I	Sodium iodide	Thyroid scanning	5	4	1,354	0.3
^{131}I	Labeled albumin	Heart scanning	69	65	546	0.1
^{87m}Sr	Nitrate or chloride	Bone scanning	130	22	438	0.1
^{197}Hg	Mercurihydroxypropane	Spleen scanning	247	57	389	0.1
^{131}I	Labeled albumin (MAA)	Liver scanning	9	4	311	†
^{99m}Tc	Pertechnetate	Thyroid scanning	5	5	259	†
^{99m}Tc	Labeled albumin	Placenta scanning	12	12	254	†
^{99m}Tc	Labeled albumin	Lung scanning	1	1	200	†
Total for principal procedures listed above					407,693	99.6
Total for 25 other procedures with less than 200 administrations (Appendix B)					1,768	0.4
Total for all scanning procedures					409,461	100.0

* Administrations using either ^{131}I or ^{125}I.

† The percentages for these entries total 0.2.

Table 6. Relative frequency of organ scanning

Organ	Percent
Thyroid	37.8
Brain	30.0
Liver	16.3
Kidney	6.2
Lung	5.6
Other	4.1
Total	100.0

advantages over the previously mentioned radionuclides in detecting brain tumors and in minimizing patient radiation dose.

There were three commonly used liver scanning agents in 1966. Colloid ^{198}Au and ^{131}I-labeled rose bengal were used for more than 90 percent of the liver scanning administrations. Sulfur-colloid labeled with ^{99m}Tc has been recently introduced, and on the basis of the experience of ^{99m}Tc application to brain scanning, it should find increased application in liver scanning in the future.

The relative frequencies of the various radionuclides used in scanning are shown in Table 7 for the various body organs.

Radiopharmaceutical Therapy. Table 8 lists the principal radiopharmaceutical therapy procedures performed during 1966. The number of administrations of ^{131}I for all therapeutic uses is 76.2 percent of all patient therapeutic administrations; and the number of patient administrations for hyperthyroidism represents 74 percent of all therapeutic administrations of ^{131}I reported in this study. Therefore, the number of administrations of ^{131}I for hyperthyroidism is greater than that for all other radiopharmaceutical therapy procedures reported, and

Table 7 Frequency of radionuclides used in organ scanning

Radionuclide	Percent							
	Bone	Brain	Kidney	Liver	Lung	Placenta	Spleen	Thyroid
^{198}Au	--	--	--	63	--	--	1	--
^{51}Cr	--	--	--	--	--	4	78	--
^{197}Hg	--	15	28	--	--	--	18	--
^{203}Hg	--	31	64	--	--	--	1	--
^{131}I	--	3	8	30	99	90	--	100
^{85}Sr	93	--	--	--	--	--	--	--
^{87m}Sr	7	--	--	--	--	--	--	--
^{99m}Tc	--	51	--	7	1	6	2	--

Table 8   Principal radiopharmaceutical therapy procedures performed during 1966

Radionuclide	Compound	Treatment	Physicians licensed for procedure	Physicians performing procedure	Patient administrations	
					Number	Percent
^{131}I	Sodium iodide	Hyperthyroidism	1,229	1,042	20,717	61.4
^{32}P	Soluble phosphate	Polycythemia vera	1,086	581	3,405	10.1
^{131}I	Sodium iodide	Thyroid ablation	869	295	2,316	6.9
^{32}P	Colloidal phosphate	Malignant effusions	724	316	2,033	6.0
^{131}I	Sodium iodide	Thyroid cancer	907	334	1,768	5.2
^{32}P	Soluble phosphate	Leukemia	819	132	933	2.8
^{131}I	Sodium iodide	Cardiac dysfunction	825	224	927	2.7
^{198}Au	Colloidal gold	Malignant effusions	681	152	732	2.2
^{32}P	Soluble phosphate	Osseous metastases	50	41	701	2.1
Total for principal procedures listed above --					33,532	99.4
Total for 8 other procedures with less than 100 administrations (Appendix B)----------					211	0.6
Total for all radiopharmaceutical therapy procedures ----------------------------------					33,743	100.0

attests to the successful use of internally administered radioiodine in the treatment of this disease.

Brachytherapy

The principal brachytherapy procedures reported are listed in Table 9. Radium is the most widely used of the seven radionuclides listed, accounting for 58 percent of the total number of treatments. The primary use of radium was for the intracavitary treatment of cancer. As previously stated, radium can be used without a license and only the licensed or registered practitioners are represented in the survey; therefore the number of administrations reported for radium is less than the actual number administered.

Teletherapy

The survey results for teletherapy procedures are summarized in Table 10. The survey respondents reported that 157,078 patients had received a total of 1,919,948 teletherapy administrations during the year 1966, for an average of about 12 administrations per patient. The only condition reported as treated by teletherapy was cancer, and the only radionuclides used were ^{60}Co and ^{137}Cs. Ninety-seven percent of these treatments were made using ^{60}Co teletherapy units.

Research

A wide variety of research studies was reported by the survey respondents. The 21 most frequently reported research studies are listed in Table 11. Many of the diagnostic research studies reported were not specifically described, and so they are listed as metabolic studies. Only 181 therapy research studies were reported for the year 1966.

Table 9. Principal brac therapy procedures performed during 1966

Radionuclide	Composition	Proce ure	Physicians licensed for procedure	Physicians performing procedure	Patient administrations	
					Number	Percent
^{226}Ra	Sealed sources	Intracavitary Rx of cancer	734	543	15,700	31.6
^{90}Sr	Eye applicator	Ophthalmic tr atment	483	295	11,785	23.7
^{226}Ra	Plaques and moulds	Dermatologica treatment	378	109	5,582	11.2
^{226}Ra	Needles	Interstitial x of cancer	604	276	4,152	8.4
^{222}Rn	Seeds	Interstitial x of cancer	436	158	3,069	6.2
^{60}Co	Needles or seeds	Intracavitary Rx of cancer	283	90	2,737	5.5
^{226}Ra	Nasopharyngeal applicator	Intracavitary Rx of cancer	306	50	2,457	5.0
^{90}Sr	Plaques	Dermatologica treatment	8	7	1,182	2.4
^{90}Sr	Nasopharyngeal applicator	Nonmalignant onditions	6	6	678	1.4
^{137}Cs	Sealed sources	Intracavitary Rx of cancer	22	16	548	1.1
^{60}Co	Needles, wire, and so forth	Interstitial x of cancer	258	31	547	1.1
^{192}Ir	Seeds - nylon ribbon	Interstitial x of cancer	51	32	404	0.8
^{226}Ra	Nasopharyngeal applicator	Nonmalignant onditions	18	12	383	0.8
^{198}Au	Seeds	Interstitial x of cancer	20	12	106	0.2
^{226}Ra	Eye applicator	Ophthalmic t atment	7	6	100	0.2
Total for principal procedures listed above					49,430	99.6
Total for 9 other procedures with less than 100 admin strations (Appendix B)					192	0.4
Total for all brachytherapy procedures					49,622	100.0

Table 10. Principal teletherapy procedures performed during 1966

Radionuclide	Procedure	Physicians licensed for procedure	Physicians performing procedure	Patients	Patient administrations	
					Number	Percent
^{60}Co	Beam therapy	524	399	153,714	1,859,845	97
^{137}Cs	Beam therapy	76	25	3,364	60,103	3
Total for all teletherapy procedures ------------------------				157,078	1,919,948	100

Table **11.** Principal research studies performed during 1966

Radionuclide	Compound	Study (as reported in survey questionnaire)	Physicians performing procedure	Administrations	
				Number	Percent
^{131}I	Labeled hormones	Metabolic	14	2,679	16.3
^{3}H and ^{14}C	Labeled aldosterone	Metabolic	4	922	5.6
^{131}I	Labeled albumin	Blood volume	8	752	4.6
^{14}C	Labeled cholesterol	Metabolic	7	408	2.5
^{14}C	Labeled steroids	Metabolic	6	352	2.1
^{3}H	Labeled cholesterol	Metabolic	5	346	2.1
^{3}H	Labeled aldosterone	Adrenal secretion	12	324	2.0
^{133}Xe	Saline solution	Blood flow	5	313	1.9
^{99m}Tc	Labeled albumin	Lung scanning	5	313	1.9
^{85}Kr	Gas	Brain blood flow	4	298	1.8
^{133}Xe	Gas	Muscle blood flow	6	290	1.8
^{85}Kr	Saline solution	Cardiac output	7	289	1.8
^{3}H	Labeled thymidine	Autoradiography	3	280	1.7
^{59}Fe	Ferric chloride	Iron absorption	4	274	1.7
^{131}I	Labeled albumin (MAA)	Lung scanning	5	256	1.6
^{14}C	Labeled cortisol	Plasma clearance	8	227	1.4
^{47}Ca	Calcium chloride	Metabolic	10	218	1.3
^{113m}In	Iron complex	Lung scanning	4	211	1.3
^{3}H	Labeled steriods	Metabolic	2	206	1.3
^{131}I	Labeled human F.S.H.	Radioimmunoassay	1	200	1.2
^{99m}Tc	Labeled albumin	Heart scanning	5	200	1.2
Total for principal procedures listed above --------------------				9,358	57.1
Total for 289 other procedures with less than 200 administrations (Appendix B) ------------------------------------				6,869	41.8
Total for all therapeutic research procedures ------------------				181	1.1
Total for all research procedures -------------------------------				16,408	100.0

The frequency with which the 30 principal radionuclides were used for diagnostic research is shown in Table 12. Four of the radionuclides, ^{131}I, ^{125}I, ^{14}C, and ^{3}H, were used in 67 percent of the research studies performed.

Appended Data

A detailed listing of the data reported for all procedures is given in Appendix B.

Table 12. Principal radionuclides used in diagnostic research studies performed during 1966

Radionuclide	Patient administrations		Radionuclide	Patient administrations	
	Number	Percent		Number	Percent
^{131}I*	5,825	35.8	^{18}F	114	0.7
^{3}H	3,315	20.4	^{24}Na	113	0.7
^{14}C	1,854	11.4	^{132}I	100	0.6
^{99m}Tc	827	5.1	^{32}P	92	0.6
^{85}Kr	620	3.8	^{137m}Ba	85	0.5
^{133}Xe	603	3.7	^{57}Co	68	0.4
^{51}Cr	490	3.0	^{198}Au	45	0.3
^{47}Ca	364	2.2	^{64}Cu	42	0.3
^{75}Se	349	2.1	^{45}Ca	31	0.2
^{59}Fe	277	1.7	^{131}Cs	30	0.2
^{113m}In	211	1.3	^{95}Zr	25	0.2
^{42}K	203	1.3	^{28}Mg	20	0.1
^{35}S	171	1.1	^{55}Fe	18	0.1
^{22}Na	163	1.0	^{60}Co	15	0.1
^{85}Sr	125	0.8	^{197}Hg	15	0.1
Total for principal radionuclides listed above -------------				16,210	99.8
Total for 5 other radionuclides (Appendix B) ---------------				17	0.2
Total for all radionuclides used in diagnostic research ----				16,227	100.0

* Those procedures using both ^{131}I and ^{125}I.

III THE NONRESPONDING POPULATION

In any survey there is concern that the nonresponding population will be of a different character than the responding population. Hence, conclusions drawn on the basis of information obtained from the responders may not be valid for the nonresponders. In many surveys where checks have been made, the two populations have been found to be divergent; therefore, it is desirable to perform a followup survey of a sample of the nonrespondents. This is especially necessary in surveys, such as this one, where the nonrespondents initially represented a large proportion of the total population.

The Followup Surveys

Five followup surveys of the nonresponding population have been made in this study.

In the first followup survey, questionnaires were mailed to all of the 4,328 physicians who did not respond to the original mailing. The questionnaire used in this mailing was identical to that used in the original survey.

In the second followup survey, telephone calls were placed to a random sample of 178 physicians who did not respond to either of the two mailings. They were asked (1) if they used radionuclides for medical purposes in 1966, and (2) for what purposes they used them. The physicians telephoned were not asked to provide data on the number of patients or the number of administrations made during 1966, since this information usually requires reference to written records.

In the third followup survey, a letter was sent to physicians who responded to the original or first followup surveys and in addition had been identified as being associated with a group practice or an institution. Approximately 1,264 nonresponding physicians were included in this survey. The responding physician was asked to describe each of the nonresponders at his institution according to one of the following four categories: (1) the physician used radioactive materials in his practice in 1966; (2) the radionuclide procedures performed by the physician were included in another response; (3) the physician did not use radioactive materials in his practice in 1966; or, (4) the physician was not at the institution in 1966.

In the fourth followup survey a letter was sent to physicians at addresses from which no response had been received in the original and the first followup surveys. A total of 1,752 physicians was included in this group. Each physician was asked to indicate whether he used radionuclides in his practice in 1966. If there were three or more nonresponding physicians at an address, a single letter was addressed to two of the physicians listing other physicians at that address about whom information was desired.

In the fifth and final followup survey, a random sample of 202 physicians was selected from the 1,058 physicians identified by the third and fourth followup surveys as having used radionuclides in 1966, but whose response was not included in the original or in the first two followup surveys. A slightly shortened version of the original questionnaire was sent to these physicians, requesting quantitiative data on numbers of patients and administrations by procedure.

The overall response to the original and the five followup surveys amounted to 85 percent of the survey population.

Followup Survey Results

The number of users of radionuclides among the physicians of the followup survey population, i.e., those physicians who did not respond to the original or first followup surveys, was determined to be 1,491. The responses to the various followup surveys and the details of the determination of the number of radionuclide users in the followup survey population are contained in Appendix C.

The usage characteristics of the radionuclide users in the followup survey population were determined from the fifth followup survey. The results of this survey, which are shown in Appendix C, gave the number of physicians performing the various procedures, the number of patients, and the number of administrations.

Comparisons of the amounts of radionuclide usage, i.e., procedures per user, patients per procedure, and administrations per patient, for the physicians reporting usage in the original, the first followup, and the fifth followup surveys are given in Appendix C. The differences in the responses for these three surveys are generally small; however, there is some indication that the users in the fifth followup survey have more patients for brachytherapy and teletherapy than do the other respondents.

Projections of Total Radionuclide Usage in Medicine in 1966

The radionuclide usage characteristics of the followup survey population was applied to the number of users in this population. This was added to the data obtained from the 54 percent of the survey population who had responded to the original and first followup surveys. The resultant projection of the total use of radionuclides in medicine during 1966 is shown in Table 13.

Comparison with 1959 Study of Radionuclide Usage in in Medicine

A study conducted by SRI for the AEC estimated that a total of 400,000 doses of radiopharmaceuticals were administered to humans during the year 1959, exclusive of teletherapy and brachytherapy.* A comparison between the 1959 study and this study by principal radionuclides is summarized in Table 14. The projected value of approximately 1,575,000 radiopharmaceutical administrations made during the year 1966, exclusive of teletherapy and brachytherapy, indicates that the number of radiopharmaceutical administrations per year has increased approximately fourfold during the seven-year period.

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* R. Tarrice and M. S. Blumberg, op cit.

Table 13. Projections of the use of radionuclides in medicine during 1966 by type of practice

Type of Practice	Number Reported by 54 percent of Survey Population		Number Projected for Total Population*	
	Patients	Administrations	Patients	Administrations
Function studies				
In vitro	585,192	-	1,123,847	-
In vivo	497,854	526,476	815,426	849,554
Scanning studies	389,706	409,281	653,635	676,269
Diagnostic research	13,621	15,943	-	-
Radiopharmaceutical therapy	28,664	33,743	43,734	48,911
Brachytherapy	31,053	49,622	68,089	111,295
Teletherapy	157,078	1,919,948	499,038†	3,285,148
Therapy research	90	181	-	-
Total	1,703,258	2,955,194	3,203,769	4,971,177

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* Projections based only on those procedures for which data were obtained in the Fifth Followup Survey.

† This figure is based on the number of patients reported by 54 percent of the survey population, and projections using the reported number of teletherapy patients for the fifth followup. It leads to an estimated ratio of 3.44 administrations per patient, which is believed to be too low. A value of 269,274 patients would be expected based on 12.2 administrations per patient obtained from 54 percent of of the survey population. See footnote to Table C-4.

Table 14. Comparison* of the 1959 and 1966 studies by principal radionuclide

Radionuclide and use	Percent	
	1959	1966
^{125}I and ^{131}I		
Diagnosis		
Thyroid	66.5	47.1
Blood volume	5.5	10.4
Fat studies	2.8	0.8
Kidney	1.2	3.4
Liver	1.0	2.0
Lung	--	1.8
Tumor	0.8	--
Other	0.4	--
Therapy		
Hyperthyroid	4.1	2.0
Cardiac	0.9	0.1
Thyroid Cancer	0.3	0.3
Other	1.8	--
Total	85.3	67.9
^{32}P		
Diagnosis	0.4	---
Therapy		
Leukemia	2.7	0.1
Other	1.3	0.5
Total	4.4	0.6
^{60}Co		
Diagnosis	3.1	1.9
Therapy	0.5†	0.6
Total	3.6	2.5
^{198}Au		
Diagnosis	0.1	0.1
Therapy	0.5	0.1
Total	0.6	0.2

Radionuclide and use	Percent	
	1959	1966
^{51}Cr		
Diagnosis		
Blood volume	2.9	1.6
Other	0.1	0.7
Total	3.0	2.3
^{59}Fe		
Diagnosis	0.2	0.2
^{90}Sr		
Therapy	0.6	1.4
^{42}K		
Diagnosis	0.2	--
^{82}Br		
Diagnosis	0.3	--
^{57}Co		
Diagnosis	--	2.3
^{3}H		
Diagnosis	0.3	
^{99m}Tc		
Diagnosis	--	6.0
^{203}Hg		
Diagnosis	--	6.9
^{197}Hg		
Diagnosis	--	3.4
^{75}Se		
Diagnosis	--	0.1
^{85}Sr		
Diagnosis	--	0.6
Other	1.5	4.9
Total	100	100

[*] Based on those procedures for which data were obtained from the Fifth Followup Survey

[†] Does not include ^{60}Co teletherapy administrations.

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PHASE II

RADIOPHARMACEUTICAL HANDLING, PATIENT SAFEGUARD, AND CALIBRATION PRACTICES IN NUCLEAR MEDICINE

I APPROACH

In the administration of radiopharmaceuticals to a patient for diagnostic purposes, the patient will be exposed to some ionizing radiation. He is willing to accept whatever risk this entails for the benefits that are likely to accrue from a quick and accurate diagnosis. The practice of nuclear medicine is constantly undergoing changes designed to minimize patient radiation exposure and improve diagnostic effectiveness. Some of the innovations are the use of short half-life radionuclides, sensitive and stable radiation detection equipment, fast operating radiation imaging devices, prepackaged unit dosages of radiopharmaceuticals of uniformly high quality, radiopharmaceutical quality control procedures, frequent instrumentation calibration and standardization, and patient radiopharmaceutical blocking and accelerated elimination drugs.

However, the overall practice of nuclear medicine at any one time represents a spectrum of practitioners operating at various levels of nuclear medicine technological evolution. To achieve the Phase II study objectives of describing this practice with particular reference to those measures that minimize patient radiation exposure, it was necessary to adopt a statistical approach using a sampling of the practitioners. Accordingly, data requirements were developed and then presented to a sampling of the practitioners in the form of a survey questionnaire.

Data Requirements

Copies of the survey questionnaires are contained in Appendix D. The data requirements concern radiopharmaceutical handling, patient safeguards, and instrumentation calibration practices applied by a given practitioner working in a nuclear medical facility with a particular radiopharmaceutical procedure. Each procedure assumes the use of a certain radiopharmaceutical. Accordingly, the use of the same agent tagged with different radionuclides or different agents tagged with the same radionuclide may be different procedures. On the other hand, some procedures may be defined for more than one radioisotope of the same element. However in some cases, different radioisotopes of the same element are different procedures. The various procedures defined in this manner are listed in Appendix B.

Nuclear medicine is a very dynamic technological field and three years have elapsed since the Phase I data were obtained. Therefore, allowance was made for the practitioner to indicate alternative radionuclides that he may now be applying to a given diagnostic procedure, and also his preferred radionuclide. It should be recognized that when a practitioner has indicated a change in radionuclides, he may be performing a different procedure by the definition of this study, even though he is achieving the same diagnostic results.

A comparison of great interest in this study is the type of nuclear medical facility in which the radiopharmaceutical procedure is being performed. It is desirable to establish whether practices affecting patient radiological safety vary in any significant manner for hospitals, clinics, groups, or individual practice.

The respondent was also asked to indicate the name of the institution, so that a more detailed classification by type of practice could be established, if desired. For example, practice in a children's hospital could explain what might be at first considered extreme measures to minimize patient radiation exposure.

Several practices under the category of radiopharmaceutical handling relate to patient safety. The respondent was asked to describe his procurement practices for the radiopharmaceutical; i.e., whether it is obtained in prepared unit doses, in large bulk multi-dose lots, prepared from a generator as a short half-life daughter from a long half-life parent, or from some other source, e.g., charged particle or neutron reactions. The checks made on the radiopharmaceutical quality as it is received are also related to patient safety. These might be isotopic purity measurements as determined by gamma ray spectroscopy, or they might be specific activity assay measurements. In some procedures and with some purchasing practices it is necessary to prepare and modify the radiopharmaceutical to render it in the form in which it is administered. This might be as simple as dilution or it might be a more complicated operation such as tagging red blood cells or labeling a pharmaceutical.

After preparation and modification of the radiopharmaceutical it might be advisable in some procedures to conduct further quality assurance checks on the radiopharmaceutical before administration. These might be radioisotope purity or activity measurements, determination of bound versus nonbound activity of tagged compounds, or various physical and chemical measurements of the prepared radiopharmaceutical.

There are several measures that might be taken to minimize the radiation exposure to the patient within given procedures. Therefore, it is of interest to determine if a blocking agent is administered before the radiopharmaceutical administration that would in some cases prevent the radionuclide from seeking a specific organ. Furthermore, in some procedures agents can be administered to hasten the elimination of the radiopharmaceutical from the system. It is always desirable to minimize the administered radiopharmaceutical activity within the limits imposed by satisfactory results from the procedure and so the respondent was asked to specify average administered activity per patient for the procedure.

For any given radiopharmaceutical procedure there is a range of types of instrumentation available to the practitioner. The choice of instrumentation can affect the required administered activity and the diagnostic success, because of the difference in sensitivity and operating speed of the various devices. All radioactivity measuring instrumentation is subject to calibration drift, and absolute activity calibrations change with the radionuclide being used. Accordingly it is desirable periodically to calibrate any instrument with a radioactive reference source. In some procedures where only relative activity values are required, the calibration is more important as an indication of instrument stability.

The questionnaire was developed with the objective of obtaining good response and accurate answers. This required a format that would appeal to nuclear medical practitioners with a heavy workload. Accordingly, it had to be relatively short and require simple answers. The questionnaire that was developed required only check-off multiple choice answers or short fill-in answers. One questionnaire was designed for scanning and thyroid procedures and another separate questionnaire was designed for function tests. This latter questionnaire differed from the scanning questionnaire only in that it omitted the questions concerning radiopharmaceutical modification, which was not thought to be appropriate for these procedures. To test the adequacy of the design of these questionnaires they were pretested with a limited number of respondents. The pretesting indicated that only slight modifications were required. The pretesting program is described in Appendix E.

Data Source

The Phase II sample population was selected from a sector of the Phase I respondents. This sector consisted of physicians who reported doing one or more of the 23 radiopharmaceutical procedures listed in Table 15 during 1966. A brief description of each procedure will be found in Appendix F. These 23 procedures accounted for over 95 percent of the total number of patients, reported in Phase I, as receiving radiopharmaceuticals for diagnostic purposes. Physicians were grouped into two lists of identification numbers: (1) those physicians who reported doing any of the selected function procedures, and (2) those physicians who reported doing any of the selected scanning procedures.

The physician sampling plan is described in Appendix G. It was designed to make the probability of a physician being sampled for a procedure depend on the number of patients. It was designed to limit the number of procedures for which a physician was asked to respond to a minimum, within the limits imposed by the necessity of obtaining a sufficiently large sample for each procedure. It was also designed to limit the number of physicians receiving questionnaires on two or more procedures that use the same radionuclide. Both of these constraints were imposed to improve the response and its accuracy.

Table 15. Radiopharmaceutical procedures sampled*

Category	Procedure	Radionuclide	Chemical or Physical Form	Procedure Designation
Function	Blood volume	P-32	Sodium phosphate	F-3
		Cr-51	Sodium chromate	F-4
		I-125/131	Albumin	F-9
Function	Vitamin B-12 malabsorption	Co-57	Cyanocobalamine	F-7
		Co-60	Cyanocobalamine	F-8
Function	Fat malabsorption	I-125/131	Labeled fats and fatty acids	F-11
Function	Kidney function	I-125/131	Sodium iodohippurate	F-12
Function	Thyroid function	I-131	Sodium iodide	F-13
Scanning	Thyroid scanning	I-131	Sodium iodide	S-8
Scanning	Brain scanning	Tc-99m	Pertechnetate	S-1
		Hg-203	Labeled mercurials	S-18
		Hg-197	Labeled mercurials	S-22
Scanning	Liver scanning	Tc-99m	Colloid	S-2
		I-131	Rose bengal	S-11
		Au-198	Colloid	S-15
Scanning	Bone scanning	Sr-85	Nitrate or chloride	S-6
		Sr-87m	Nitrate or chloride	S-7
Scanning	Lung scanning	I-131	Albumin macroaggregates	S-9
Scanning	Placenta scanning	I-125/131	Albumin	S-10
		Cr-51	Sodium chromate	S-25
Scanning	Kidney scanning	I-131	Renal labeled compounds	S-12
		Hg-197	Labeled mercurials	S-13
		Hg-203	Labeled mercurials	S-17

* A brief description of these procedures may be found in Appendix F.

II RESULTS

Data Response

Survey Questionnaire Response

A total of 1,082 survey questionnaires was mailed (during the period from March 10-13, 1969) to 879 selected physicians requesting data on 23 radiopharmaceutical procedures. A second mailing was made (during the period April 17-21, 1969) to all physicians who had not responded. The response received from these two mailings is summarized in Table 16. A more detailed discussion of the response from the two mailings is contained in Appendix H.

To obtain sufficient data on several of the procedures it was necessary to send more than one questionnaire to many physicians. Table 17 shows the response as a function of the number of questionnaires mailed to individual physicians. To encourage response, those physicians receiving four or more questionnaires were telephoned shortly after the questionnaires were mailed.

The type of response and percent for each radiopharmaceutical procedure are shown in Table 18. In approximately 21 percent of the responses, the practitioner indicated that he had changed radionuclides for the procedure. If a radionuclide change had been indicated and the questionnaire was not completed for the new radiopharmaceutical, or whenever incomplete questionnaires were returned, a letter requesting complete data was sent to the physician. As a result of good response to this request, only 26 questionnaires remain with incomplete data.

It was indicated on about 13 percent of the questionnaires returned that the physician was no longer performing the procedure. This category includes such responses as: retired, promoted, changed practices, and refers patients to another practitioner. Three physicians returned five questionnaires that they refused to complete.

Table 16. Response to questionnaire mailings to physicians

Response Category	Response		
	First Mailing	Second Mailing	Total of Mailings
Physicians	552 (62.7%)	197 (60.2%)	749 (85.2%)
Questionnaires	698 (64.5%)	226 (58.9%)	924 (85.4%)

Table 17. Response vs number of questionnaires mailed to a physician

Questionnaires Mailed	Number of Physicians		Percent Response
	Receiving	Responding	
1	741	630	85.0
2	86	75	87.2
3	44	37	84.1
4	5	4	80.0
5	2	2	100.0
6	1	1	100.0

Table 18. Type of response for radiopharmaceutical procedure questionnaires

Procedure	Number of Responses									Procedure Percent Response
	Using Same Radionuclide		Changed Radionuclide		No Longer Doing Procedure	Deceased	Refused to Answer	Sabbatical Leave	Procedure Total	
	Complete Data	Incomplete Data	Complete Data	Incomplete Data						
P-32 Blood Volume (F-3)	2	0	10	2	15	0	0	0	29	90.7
Cr-51 Blood Volume (F-4)	28	0	9	0	9	0	0	0	46	92.0
Co-57 Vitamin B-12 (F-7)	38	0	1	0	3	0	1	0	43	86.0
Co-60 Vitamin B-12 (F-8)	17	0	17	0	5	0	1	0	40	80.0
I-125/131 Blood Volume (F-9)	35	0	0	0	4	0	1	0	40	78.4
I-125/131 Fat Absorption (F-11)	40	0	1	0	4	0	0	0	45	90.0
I-125/131 Kidney Function (F-12)	41	1	1	0	5	0	0	0	48	97.0
I-131 Thyroid Function (F-13)	37	1	0	0	4	0	1	0	43	87.7
Tc-99m Brain Scan (S-1)	39	0	0	0	3	0	0	1	43	86.0
Tc-99m Liver Scan (S-2)	27	0	7	2	9	0	0	0	45	81.8
Sr-85 Bone Scan (S-6)	43	0	1	0	1	0	0	0	45	84.9
Sr-87m Bone Scan (S-7)	5	1	7	0	5	0	0	0	18	90.0
I-131 Thyroid Scan (S-8)	36	0	2	0	3	0	0	0	41	82.0
I-131 Lung Scan (S-9)	36	0	5	0	5	0	0	0	46	86.8
I-125/131 Placenta Scan (S-10)	34	1	6	0	5	0	0	0	46	92.0
I-131 Liver Scan (S-11)	26	0	13	2	5	0	0	0	46	90.1
I-131 Kidney Scan (S-12)	14	1	14	1	11	0	0	0	41	85.4
Hg-197 Kidney Scan (S-13)	26	1	11	1	6	0	0	0	45	86.5
Au-198 Liver Scan (S-15)	29	1	6	1	2	0	0	0	39	75.0
Hg-203 Kidney Scan (S-17)	15	1	13	2	6	1	1	0	39	76.4
Hg-203 Brain Scan (S-18)	5	0	29	2	4	0	0	0	40	80.0
Hg-197 Brain Scan (S-22)	8	0	27	4	4	0	0	0	43	82.7
Cr-51 Placenta Scan (S-25)	9	0	2	1	1	0	0	0	13	100.0
Total	590	8	182	18	119	1	5	1	924	

The overall percentages of types of responses may be calculated from the data of Table 18. These results are given in Table 19.

Table 19. General types of responses for survey questionnaires

Response Type	Number of Questionnaires	Percent of Total Responses
Using same radionuclide (complete data)	590	63.9
Using same radionuclide (incomplete data)	8	0.9
Subtotal using same radionuclide	(598)	64.8
Changed radionuclide (complete data)	182	19.7
Changed radionuclide(incomplete data)	18	1.9
Subtotal changed radionuclide	(200)	21.6
Total reported active practitioners	(798)	86.4
No longer doing the procedure	119	12.9
Deceased	1	0.1
Refused to answer	5	0.5
On sabbatical leave	1	0.1

Radionuclide Changes Within Procedures

As indicated in Table 19, physicians reported changing radionuclides in 21.6 percent of the questionnaires received. These changes in radionuclides are listed in detail in Table 20, which shows the radionuclides currently utilized by the 798 reported procedure users for each of the 23 procedures sampled. The procedures were sampled on the basis of their use by physicians in 1966. A change in radionuclides by physicians of this extent within a three-year period is an indication of the pace of technical development in the practice of nuclear medicine.

The radiopharmaceutical procedures samples were defined as using a specific radionuclide. Except for some of the procedures that specified either ^{125}I or ^{131}I, the use of different radioisotopes of the same element was also defined as different procedures. For example, kidney

Table 20. Radionuclides currently used in procedures sampled

Procedure Sampled Based on 1966 Use	Number of Responding Physicians Using Radionuclide in 1969*																Procedure Total
	Au-198	Co-57	Co-60	Cr-51	I-125	I-131	I-125/131	Hg-197	Hg-203	P-32	Sr-85	Sr-87m	Tc-99m	In-113m	F-18	H-3	
P-32 Blood Volume (F-3)	0	0	0	4	0	8	0	0	0	2	0	0	0	0	0	0	14
Cr-51 Blood Volume (F-4)	0	0	0	28	5	3	1	0	0	0	0	0	0	0	0	0	37
Co-57 Vitamin B-12 (F-7)	0	38	1	0	0	0	0	0	0	0	0	0	0	0	0	0	39
Co-60 Vitamin B-12 (F-8)	0	17	17	0	0	0	0	0	0	0	0	0	0	0	0	0	34
I-125/131 Blood Volume (F-9)	0	0	0	0	8	27	0	0	0	0	0	0	0	0	0	0	35
I-125/131 Fat Absorption (F-11)	0	0	0	0	0	37	3	0	0	0	0	0	0	0	0	1	41
I-125/131 Kidney Function (F-12)	0	0	0	0	1	41	0	1	0	0	0	0	0	0	0	0	43
I-131 Thyroid Function (F-13)	0	0	0	0	0	38	0	0	0	0	0	0	0	0	0	0	38
Tc-99m Brain Scan (S-1)	0	0	0	0	0	0	0	0	0	0	0	0	39	0	0	0	39
Tc-99m Liver Scan (S-2)	6	0	0	0	0	3	0	0	0	0	0	0	27	0	0	0	36
Sr-85 Bone Scan (S-6)	0	0	0	0	0	0	0	0	0	0	43	0	0	0	1	0	44
Sr-87m Bone Scan (S-7)	0	0	0	0	0	0	0	0	0	0	7	6	0	0	0	0	13
I-131 Thyroid Scan (S-8)	0	0	0	0	1	36	0	0	0	0	0	0	1	0	0	0	38
I-131 Lung Scan (S-9)	0	0	0	0	0	36	0	0	0	0	0	0	4	1	0	0	41
I-125/131 Placenta Scan (S-10)	0	0	0	1	2	32	1	0	0	0	0	0	5	0	0	0	41
I-131 Liver Scan (S-11)	11	0	0	0	0	26	0	0	0	0	0	0	4	0	0	0	41
I-131 Kidney Scan (S-12)	0	0	0	0	1	15	0	6	8	0	0	0	0	0	0	0	30
Hg-197 Kidney Scan (S-13)	0	0	0	0	1	1	0	27	9	0	0	0	1	0	0	0	39
Au-198 Liver Scan (S-15)	30	0	0	0	0	2	0	0	0	0	0	0	5	0	0	0	37
Hg-203 Kidney Scan (S-17)	0	0	0	0	0	0	0	15	16	0	0	0	0	0	0	0	31
Hg-203 Brain Scan (S-18)	0	0	0	0	0	1	0	0	5	0	0	0	30	0	0	0	36
Hg-197 Brain Scan (S-22)	0	0	0	0	0	0	0	8	1	0	0	0	30	0	0	0	39
Cr-51 Placenta Scan (S-25)	0	0	0	9	0	0	0	0	0	0	0	0	3	0	0	0	12
Total	47	55	18	42	19	306	5	57	39	2	50	6	140	1	1	1	798

* Includes 772 complete and 26 incomplete responses.

scanning with ^{197}Hg or ^{203}Hg labeled mercurials are different procedures. Accordingly, the specification of a different radionuclide by a practitioner usually meant that he was no longer performing the procedure sampled. Where changes in radionuclides were indicated, it was determined if the procedure with the changed radionuclide was the same as another of the 23 procedures originally sampled. If this was the case, the data were included in the analysis of the corresponding procedure. All but 22 of the reported 195 radionuclide changes did correspond to one of the original 23 sampled procedures. These 22 sets of data were therefore excluded from the subsequent analyses. However, the radionuclides being used by these practitioners are reported in Appendix I.

Resultant Usable Data

The radionuclide changes described above did result in transfers of data within the various procedures. The resultant number of complete sets of data available for each procedure is listed in Table 21. The sample size of complete data for detailed analysis is quite small for some of the procedures.

Rules were adopted for deciding if sufficient data were available for detailed analysis of a procedure. The sample size was considered adequate if (1) 20 or more complete sets of data were available for the procedure or if (2) the sample size of complete data sets for the procedure exceeded 80 percent of the number of questionnaires mailed. In those cases where the sample size was less than 80 percent of the number of questionnaires mailed, summaries were made of the yes or no type questions if the sample size was in the range of 15 to 19 complete data sets; however, for those procedures in this range, no detailed analyses were made. Using these criteria there was insufficient response for procedures F-3, S-7, S-18, S-22; and only yes and no type answers for procedures F-8 and S-12 were included in the analyses. However, summaries of the unused data are given in Appendix I.

Since a stratified sample was used for each radiopharmaceutical procedure, each response was assigned a weighting factor that depended on the number of physicians in the strata and the number of physicians sampled from the strata. Accordingly, in the data analyses all averages and frequencies were calculated using the appropriate weighting factor.

Table 21. Data available for analysis of each procedure

Procedure	No. of Questionnaires Mailed for Procedure	No. of Respondents	Total No. of Complete Data Sets After Radionuclide Changes*
P-32 Blood Volume (F-3)	32	29	2
Cr-51 Blood Volume (F-4)	50	46	31
Co-57 Vitamin B-12 (F-7)	50	43	55
Co-60 Vitamin B-12 (F-8)	50	40	18
I-125/131 Blood Volume (F-9)	51	40	51
I-125/131 Fat Absorption (F-11)	50	45	40
I-125/131 Kidney Function (F-12)	50	48	41
I-131 Thyroid Function (F-13)	49	43	37
Tc-99m Brain Scan (S-1)	50	43	93
Tc-99m Liver Scan (S-2)	55	45	34
Sr-85 Bone Scan (S-6)	53	45	50
Sr-87m Bone Scan (S-7)	20	18	5
I-131 Thyroid Scan (S-8)	50	41	36
I-131 Lung Scan (S-9)	53	46	36
I-125/131 Placenta Scan (S-10)	50	46	34
I-131 Liver Scan (S-11)	51	46	30
I-131 Kidney Scan (S-12)	48	41	15
Hg-197 Kidney Scan (S-13)	52	45	44
Au-198 Liver Scan (S-15)	52	39	44
Hg-203 Kidney Scan (S-17)	51	39	32
Hg-203 Brain Scan (S-18)	50	40	6
Hg-197 Brain Scan (S-22)	52	43	8
Cr-51 Placenta Scan (S-25)	13	13	10

* Excludes 22 radionuclide changes which do not correspond to one of the procedures sampled.

Data are therefore reported on the basis of the total number of physicians performing a given procedure. It should be emphasized that the results presented are based on information received from the survey respondents only.

In most cases data are reported to three significant figures. This is done as a convenience for data comparison, and is not meant to imply that the measurements were made with this precision. Since almost 1,000 questionnaires were returned, the precision should never exceed three significant figures; and this would be justified only when all questionnaires are included. The typical result reported is based on fewer replies.

Nuclear Medical Facilities

The place of practice in which physicians perform the various procedures is shown in Table 22. The great majority of physicians who perform any of the procedures do so in hospitals. The lowest value for any of the procedures is that 76.4 percent of the physicians are engaged in hospital practice for procedure S-8, ^{131}I thyroid scanning. The procedures employed by a significant fraction of the physicians (more than 10 percent) not engaged in hospital practice, i.e., private or group practice, include thyroid uptake and scanning, the two vitamin B-12 malabsorption procedures, the two most widely used liver scanning procedures, and the most widely used kidney scanning procedure. These are all widely used procedures as determined by the Phase I study; however, other widely used procedures, e.g., brain scanning using ^{99m}Tc, are not performed by many physicians outside of hospitals.

Radiopharmaceutical Handling

Purchasing Practices

The form in which the radiopharmaceuticals are procured by the practitioners for the various procedures is shown in Table 23. The procurement policies were limited to purchases of prepared unit doses of radiopharmaceutical, multi-dose bulk lots, and a special type of multi-dose purchase that employs parent-daughter radionuclide separation.

Table 22. Place of practice

Procedure	Percent of Physicians Doing Procedure		
	Hospital Practice	Individual Office Practice	Group Practice Outside Hospital
Cr-51 Blood Volume (F-4)	94.7	--	5.3
Co-57 Vitamin B-12 (F-7)	87.8	9.1	3.2
Co-60 Vitamin B-12 (F-8)	89.4	--	10.6
I-125/131 Blood Volume (F-9)	92.0	5.1	2.9
I-125/131 Fat Absorption (F-11)	96.2	--	3.8
I-125/131 Kidney Function (F-12)	93.6	5.9	0.4
I-131 Thyroid Function (F-13)	81.2	15.4	3.4
Tc-99m Brain Scan (S-1)	97.5	1.9	0.6
Tc-99m Liver Scan (S-2)	100.0	--	--
Sr-85 Bone Scan (S-6)	92.9	3.5	3.6
I-131 Thyroid Scan (S-8)	76.4	16.3	7.3
I-131 Lung Scan (S-9)	100.0	--	--
I-125/131 Placenta Scan (S-10)	100.0	--	--
I-131 Liver Scan (S-11)	87.9	2.7	9.4
I-131 Kidney Scan (S-12)	96.6	--	3.5
Hg-197 Kidney Scan (S-13)	98.9	--	1.1
Au-198 Liver Scan (S-15)	86.4	7.5	6.1
Hg-203 Kidney Scan (S-17)	83.2	13.1	3.7
Cr-51 Placenta Scan (S-25)	100.0	--	--

Table 23. Radiopharmaceutical purchasing practices by procedure

Procedure	Percent of Physicians Doing Procedure				
	Unit Dose Procurement	Multi-Dose Procurement	Generator Procurement	Unit-Dose and Multi-Dose Procurement	Multi-Dose and Generator Procurement
Cr-51 Blood Volume (F-4)	16.0	64.2	--	19.8	--
Co-57 Vitamin B-12 (F-7)	98.2	1.8	--	--	--
Co-60 Vitamin B-12 (F-8)	91.6	8.5	--	--	--
I-125/131 Blood Volume (F-9)	85.2	14.8	--	--	--
I-125/131 Fat Absorption (F-11)	88.0	12.0	--	--	--
I-125/131 Kidney Function (F-12)	4.5	95.5	--	--	--
I-131 Thyroid Function (F-13)	79.6	17.5	--	2.9	--
Tc-99m Brain Scan (S-1)	12.1	24.7	61.6	0.3	1.3
Tc-99m Liver Scan (S-2)	--	5.5	94.5	--	--
Sr-85 Bone Scan (S-6)	40.9	59.1	--	--	--
I-131 Thyroid Scan (S-8)	71.8	28.2	--	--	--
I-131 Lung Scan (S-9)	22.7	77.3	--	--	--
I-125/131 Placenta Scan (S-10)	62.5	37.5	--	--	--
I-131 Liver Scan (S-11)	4.5	95.5	--	--	--
I-131 Kidney Scan (S-12)	4.8	95.2	--	--	--
Hg-197 Kidney Scan (S-13)	19.6	80.4	--	--	--
Au-198 Liver Scan (S-15)	7.8	92.2	--	--	--
Hg-203 Kidney Scan (S-17)	25.5	73.5	--	1.0	--
Cr-51 Placenta Scan (S-25)	7.8	92.2	--	--	--

The purchasing practices will be affected by the decay characteristics of the radionuclide, the properties of the labeled pharmaceutical, and the requirements of the procedure. Accordingly, the purchasing practices are shown in Table 24 for the various radionuclides used.

The only radionuclide that a significant fraction of physicians procure in the form of a generator is ^{99m}Tc. This radionuclide has a short half-life of 6 hours and is the daughter of ^{99}Mo, which has a half-life of 66 hours. Therefore it possesses a convenient parent-daughter relationship for a generator, and the usage of this radionuclide in medicine has increased dramatically since the introduction of commercial generators.

More than one-half of the physicians procure unit doses of radiopharamceuticals for the vitamin B-12 malabsorption, the $^{125/131}$I fat malabsorption, the ^{131}I iodide thyroid uptake and scanning, and the $^{125/131}$I human serum albumin blood volume and placental location procedures. This confirms the widespread commercial availability and acceptance of labeled vitamin B-12, triolein and oleic acid, and human serum albumin.

The majority of the physicians performing the remaining procedures under consideration procure the radiopharmaceutical in the form of bulk multi-dose lots. Obviously, unit doses cannot be conveniently used in those procedures requiring the adjustment of administered activity to the patient's weight, or to the sensitivity of the available radiation detection instruments. In other situations, the type and level of practice may indicate some economies in the procurement of bulk lots of radionuclides.

Quality Control of Radiopharmaceutical as Received

The testing that is performed on the radiopharmaceutical as received from the supplier by the practitioners of the various procedures is shown in Table 25. In all but two procedures, the majority of the practitioners do not perform testing but appear to rely on the supplier for quality control. These procedures, S-1 and S-2, both utilize ^{99m}Tc, which more than 60 percent of practitioners procure from generators. Generator-procured ^{87m}Sr, which is used in procedure S-7, is tested by

Table 24. Radiopharmaceutical purchasing practices by radionuclide

Radionuclide	Percent of Physicians Doing Procedure				
	Unit Dose Procurement	Multi-Dose Procurement	Generator Procurement	Unit-Dose and Multi-Dose Procurement	Multi-Dose and Generator Procurement
Cr-51	15.5	65.8	--	18.7	--
Co-57	98.2	1.8	--	--	--
Co-60	91.5	8.5	--	--	--
I-125/131	63.1	36.2	--	0.7	--
Tc-99m	10.3	21.9	66.4	0.3	1.1
Sr-85	40.9	59.1	--	--	--
Hg-197	18.0	82.0	--	--	--
Hg-203	22.1	77.0	--	0.9	--
Au-198	7.8	92.2	--	--	--

Table 25. Testing of radiopharmaceutical as-received,by procedure

Procedure	Percent of Physicians Doing Procedure						
	No Tests	Yes Tests	Isotope Purity	Activity Assay	Purity & Assay	Particle Size	Purity & Particle Size
Cr-51 Blood Volume (F-4)	78.8	21.2	5.3	10.8	5.1	--	--
Co-57 Vitamin B-12 (F-7)	65.6	34.4	1.2	31.3	1.9	--	--
Co-60 Vitamin B-12 (F-8)	67.8	32.2	Insufficient Data				
I-125/131 Blood Volume (F-9)	73.2	26.8	--	25.6	1.2	--	--
I-125/131 Fat Absorption (F-11)	66.3	33.7	--	32.4	1.3	--	--
I-125/131 Kidney Function (F-12)	78.0	22.0	--	18.7	3.3	--	--
I-131 Thyroid Function (F-13)	80.2	19.8	--	19.7	0.1	--	--
Tc-99m Brain Scan (S-1)	33.7	66.3	2.0	28.5	35.8	--	--
Tc-99m Liver Scan (S-2)	2.8	97.2	--	61.5	34.3	--	1.4
Sr-85 Bone Scan (S-6)	73.9	26.1	--	19.8	6.3	--	--
I-131 Thyroid Scan (S-8)	52.8	47.2	--	36.6	10.6	--	--
I-131 Lung Scan (S-9)	63.6	36.4	0.9	34.2	0.5	0.8	--
I-125/131 Placenta Scan (S-10)	80.2	19.8	2.7	16.4	0.7	--	--
I-131 Liver Scan (S-11)	79.6	20.4	4.7	15.7	--	--	--
I-131 Kidney Scan (S-12)	88.3	11.7	← Insufficient Data →				
Hg-197 Kidney Scan (S-13)	66.7	33.3	--	29.2	4.1	--	--
Au-198 Liver Scan (S-15)	77.8	22.2	--	21.8	0.4	--	--
Hg-203 Kidney Scan (S-17)	66.6	33.4	--	32.7	0.7	--	--
Cr-51 Placenta Scan (S-25)	84.4	15.6	--	15.6	--	--	--

a majority of the users, although only limited data were obtained.* The testing performed on generator-procured radionuclides is a check on the manipulations required to "milk" the generator as well as a check on the properties of the material as-received.

It would be expected that the manner in which the radiopharmaceuticals were procured would have some bearing on the extent and type of testing to which they are subjected. Packaged unit dose radiopharmaceuticals would be expected to be "patient ready" and so require little or no testing, while bulk multi-dose lots might be thought to justify testing if only from the consideration of the numbers of administrations that might be given from one lot. The effect of generator procurement of radiopharmaceuticals on the quality assurance testing practices has been discussed above. Accordingly, Tables 26, 27, and 28 are included to show by radionuclide rather than by procedure the quality assurance practices of physicians according to procurement practice. Some generalizations can be inferred from the tables. Those practitioners who perform testing usually conduct activity assays. Those practitioners who perform isotopic purity tests usually do so in conjunction with activity assays. Almost all of the practitioners who procure ^{99m}Tc from a generator conduct quality control tests. About as many of these practitioners conduct activity assays with isotopic purity checks as those who conduct only activity assays. In general, a larger fraction of the physicians who procure a radionuclide in multi-dose lots conduct quality assurance tests than those who procure it in unit-doses.

Handling and Preparation

Data were obtained on radiopharmaceutical modification practices for the scanning and the thyroid uptake function procedures. These modification practices apply particularly to these procedures and not to the other function procedures under consideration. The radiopharmaceutical modifications performed by the practitioners of each procedure are shown in Table 29.

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* See Tables I-3 and I-4 of Appendix I for data on purchasing and testing practices for procedures S-7.

Table 26. Testing of radiopharmaceuticals procured as generators

Radionuclide	Percent of Physicians Using Radionuclide Obtained from Generators					
	No Tests	Yes Tests	Isotopic Purity	Activity Assay	Purity & Assay	Purity & Particle Size
Tc-99m	7.3	92.7	0.9	42.1	49.4	0.3
Sr-87m	--	100.0	--	25	27	--

Table 27. Testing of radiopharmaceuticals procured in unit doses, by radionuclide

Radionuclide	Percent of Physicians Using Unit-Dose Radionuclide				
	No Tests	Yes Tests	Isotopic Purity	Activity Assay	Purity & Assay
Cr-51	100.0	--	--	--	--
Co-57	66.8	33.2	0.9	30.3	2.0
Co-60	66.9	33.1	--	33.1	--
I-125/131	75.9	24.1	0.2	22.3	1.6
Tc-99m	82.7	17.3	--	17.3	--
Sr-85	61.4	38.6	--	34.2	4.4
Hg-197	100.0	--	--	--	--
Hg-203	78.8	21.2	--	21.2	--
Au-198	100.0	--	--	--	--

Table 28. Testing of radiopharmaceuticals procured in multi-dose lots, by radionuclide

Radionuclide	Percent of Physicians Using Multi-Dose Lots of Radionuclide					
	No Tests	Yes Tests	Isotopic Purity	Activity Assay	Purity & Assay	Particle Size
Cr-51	73.6	26.4	7.7	16.9	1.8	--
Co-57	--	100.0	20.0	80.0	--	--
Co-60	77.6	22.4	--	--	22.4	--
I-125/131	63.9	36.1	1.1	30.7	4.0	0.3
Tc-99m	71.9	28.1	--	15.5	12.6	--
Sr-85	82.5	17.5	--	9.9	7.6	--
Hg-197	60.3	39.7	--	33.3	6.4	--
Hg-203	61.4	38.6	--	35.1	3.5	--
Au-198	75.9	24.1	--	23.6	0.5	--

Table 29. Modification of radiopharmaceuticals

Procedure	Percent of Physicians Doing Procedure			
	No Modification	Yes Modification	Dilution	Tagging
I-131 Thyroid Function (F-13)	87.4	12.6	12.6	--
Tc-99m Brain Scan (S-1)	74.2	25.8	24.8	1.0
Tc-99m Liver Scan (S-2)	5.5	94.5	6.9	87.5
Sr-85 Bone Scan (S-6)	93.1	6.9	6.9	--
I-131 Thyroid Scan (S-8)	87.4	12.6	12.6	--
I-131 Lung Scan (S-9)	84.1	15.9	15.9	--
I-125/131 Placenta Scan (S-10)	84.1	15.9	15.9	--
I-131 Liver Scan (S-11)	99.4	0.6	0.6	--
I-131 Kidney Scan (S-12)	93.1	6.9	Insufficient Data	
Hg-197 Kidney Scan(S-13)	100.0	--	--	--
Au-198 Liver Scan (S-15)	94.7	5.3	5.3	--
Hg-203 Kidney Scan (S-17)	89.2	10.8	10.8	--
Cr-51 Placenta Scan (S-25)	68.8	31.3	--	31.3

It is apparent that virtually all of the physicians performing procedures S-2 modify the radiopharmaceutical before administration. In this procedure sulfur colloid is tagged with ^{99m}Tc. Tagging was also indicated as the modification performed by about a third of the physicians performing procedure S-25 (^{51}Cr tagged red blood cells utilized in placental location). Most of the other physicians conducting modifications performed simple dilutions, but in all of the procedures except S-2, the great majority of physicians reported no radiopharmaceutical modification.

Quality Control of Administered Radiopharmaceutical

The quality control tests that are performed by the physicians who administer modified radiopharmaceuticals are shown in Table 30 for each procedure. The majority of the physicians who use modified radiopharmaceuticals conduct some testing of the radiopharmaceutical before administration. Almost all of the physicians who perform tests include an activity assay. On the procedure S-2, liver scanning with ^{99m}Tc, which always requires a tagging modification, most practitioners include a check for isotopic purity, an activity assay, and a comparison of bound versus unbound activity.

Patient Safeguards

Blocking Agent Practices

Blocking agents are often administered to prevent the accumulation of a radionuclide in organs other than the one under study. The fraction of practitioners who administer blocking agents is shown in Table 31 for each procedure. The majority of the practitioners of procedures F-11, S-9, S-10, and S-1 administer blocking agents before administering the radiopharmaceutical. The first three of these procedures use radioiodine tagged materials, and blocking agents in the form of iodides are administered to prevent the accumulation of radioiodine in the thyroid. In procedure S-1, brain scanning with ^{99m}Tc, potassium perchlorate is often given before administering the radiopharmaceutical to prevent the concentration of pertechnetate by the choroid plexus. A concentration of activity in this area of the brain can cause confusion in interpretation of the scan.

Table 30. Testing of modified radiopharmaceutical

Procedure	Percent of Physicians Doing Procedure with Modified Radiopharmaceutical								
	No Tests	Yes Tests	Isotope Purity	Activity Assay	Bound vs Unbound Activity	pH	Pyrogen	Solution Clarity	Sterility
I-131 Thyroid Function (F-13)	--	100	0.8	100	--	0.8	--	1.7	--
Tc-99m Brain Scan (S-1)	--	100	84.2	97.6	4.6	9.0	--	32.8	9.5
Tc-99m Liver Scan (S-2)	1.5	98.5	69.5	88.6	98.3	40.8	29.0	33.4	17.3
Sr-85 Bone Scan (S-6)	59.7	40.3	4.2	40.3	--	20.2	16.0	4.2	--
I-131 Thyroid Scan (S-8)	27.4	72.6	13.3	72.6	--	1.3	--	35.9	--
I-131 Lung Scan (S-9)	42.9	57.1	--	57.1	--	--	57.1	57.1	--
I-125/131 Placenta Scan (S-10)	29.9	70.1	--	70.1	--	--	30.5	20.7	--
I-131 Liver Scan (S-11)	100	--	--	--	--	--	--	--	--
I-131 Kidney Scan (S-12)	100	--	--	--	--	--	--	--	--
Au-198 Liver Scan (S-15)	29.0	71.1	--	58.8	--	--	--	37.7	--
Hg-203 Kidney Scan (S-17)	--	100	--	--	--	--	100	100	--
Cr-51 Placenta Scan (S-25)	50.0	50.0	--	50.0	--	--	--	--	--

Table 31. Blocking agent practices

Procedure	Percent of Physicians Doing Procedure						
	No Blocking	Yes Blocking	Blocking Agents Utilized				
			Iodides	Perchlorates	Mercurial Diuretics	Vitamin B-12	Other
Cr-51 Blood Volume (F-4)	84.0	16.0	16.0	--	--	--	--
Co-57 Vitamin B-12 (F-7)	89.0	11.0	--	--	--	11.0	--
Co-60 Vitamin B-12 (F-8)	82.7	17.3	← Insufficient Data →				
I-125/131 Blood Volume (F-9)	88.5	11.5	11.4	--	--	--	0.1
I-125/131 Fat Absorption (F-11)	32.2	67.8	67.8	--	--	--	--
I-125/131 Kidney Function (F-12)	95.9	4.1	4.1	--	--	--	--
I-131 Thyroid Function (F-13)	98.3	1.7	--	--	--	--	1.7
Tc-99m Brain Scan (S-1)	35.1	64.9	18.9	37.4	2.7	--	5.9
Tc-99m Liver Scan (S-2)	95.8	4.2	1.4	2.8	--	--	--
Sr-85 Bone Scan (S-6)	98.9	1.1	--	--	--	--	1.1
I-131 Thyroid Scan (S-8)	100	--	--	--	--	--	--
I-131 Lung Scan (S-9)	16.9	83.1	82.0	0.3	--	--	0.8
I-125/131 Placenta Scan (S-10)	9.8	90.2	90.2	--	--	--	--
I-131 Liver Scan (S-11)	72.6	27.4	27.4	--	--	--	--
I-131 Kidney Scan (S-12)	55.9	44.1	← Insufficient Data →				
Hg-197 Kidney Scan (S-13)	87.6	12.4	--	--	12.4	--	--
Au-198 Liver Scan (S-15)	90.3	9.7	4.9	4.8	--	--	--
Hg-203 Kidney Scan (S-17)	86.9	13.1	--	--	13.1	--	--
Cr-51 Placenta Scan (S-25)	92.2	7.8	7.8	--	--	--	--

Those physicians who reported using a blocking agent in procedures F-7 and F-8 are performing the Schilling test for vitamin B-12 malabsorption. In this test a large dosage of stable vitamin is given intravenously or intramuscularly to promote renal excretion of the absorbed labeled vitamin B-12. Since this also blocks the fixation of radioactive vitamin B-12 by the liver, it can be considered to achieve the effect of a blocking agent in reducing patient radiation exposure.

Radiopharmaceutical Dosages

The administered radiopharmaceutical activity per patient as reported is shown in Table 32 for each procedure. Each respondent was asked to report the average patient dosage for the procedure. The range of values reported as well as the average values are shown in the table. Those dosages that were reported on the basis of patient weight were converted to microcurie values by assuming a 70-kilogram adult patient. The average value is weighted to represent all physicians performing a given procedure. The reported values are also presented as frequency histograms in Figure 1. The average values compare favorably with the most frequently reported values as represented by the peak values in the histograms. With one exception the average value and the most frequently reported value are within the range of values reported in well-known references in the field of nuclear medicine.* This exception is procedure F-4, ^{51}Cr Sodium Chromate Blood Volume Determination, where it is suspected that many respondents reported the activity used to tag the red blood cells rather than reporting the administered dosage.

Accelerated Elimination Practices

The extent of the practice to accelerate the elimination of radionuclides from the patient is shown in Table 33. This method for minimizing patient radiation exposure is used by greater than 25 percent of the practitioners in only two procedures, F-7 and S-6, ^{57}Co cyanocobalamine

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* Silver, Solomon, M.D., Radioactive Nuclides in Medicine and Biology, Third Edition, Philadelphia, Lea & Febiger, 1968.
Wagner, Henry J. Jr., M.D., ed., Principles of Nuclear Medicine, Philadelphia, W. B. Saunders Company, 1968.

Table 32. Administered radiopharmaceutical dosages

Procedure	Administered Activity per Patient, μCi		
	Average of All Practitioners	Range of Values Reported by Sample of Practitioners	
		Minimum	Maximum
CR-51 Blood Volume (F-4)	27.33	3.00	50.00
Co-57 Vitamin B-12 (F-7)	0.50	0.10	1.40
I-125/131 Blood Volume (F-9)	5.50	0.50	22.50
I-125/131 Fat Absorption (F-11)	44.44	15.00	100.00
I-125/131 Kidney Function (F-12)	45.01	3.00	150.00
I-131 Thyroid Function (F-13)	36.86	2.50	100.00
Tc-99m Brain Scan (S-1)	7,936.59	600.00	15,000.00
Tc-99m Liver Scan (S-2)	2,971.61	700.00	8,000.00
Sr-85 Bone Scan (S-6)	104.97	50.00	300.00
I-131 Thyroid Scan (S-8)	56.86	10.00	150.00
I-131 Lung Scan (S-9)	260.44	100.00	350.00
I-125/131 Placenta Scan (S-10)	7.07	1.50	15.00
I-131 Liver Scan (S-11)	157.71	55.00	400.00
Hg-197 Kidney Scan (S-13)	144.42	45.00	300.00
Am-198 Liver Scan (S-15)	174.97	60.00	500.00
Hg-203 Kidney Scan (S-17)	116.58	70.00	280.00
Cr-51 Placenta Scan (S-25)	23.94	5.00	50.00

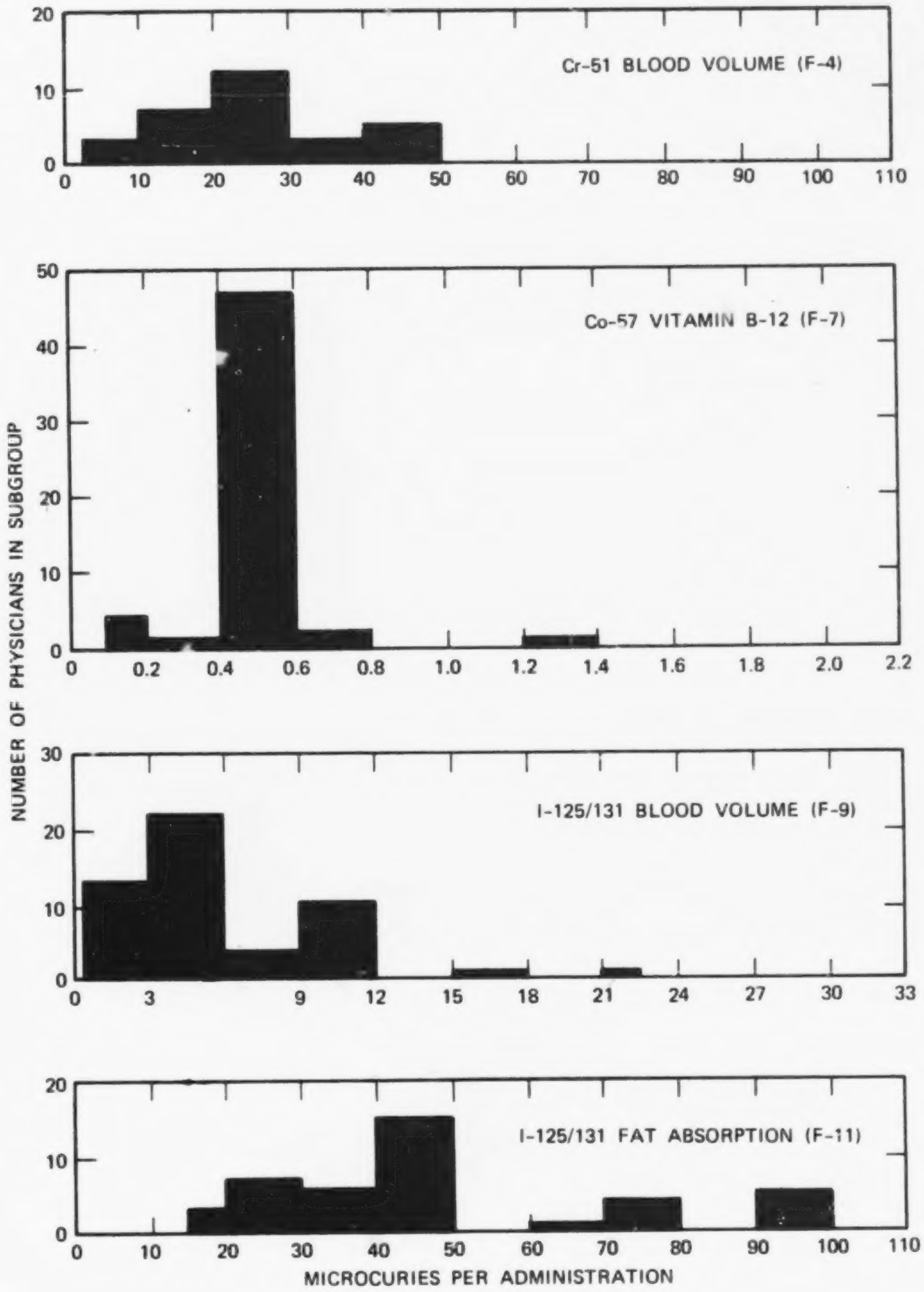

Figure 1. Frequency histograms of average administered radiopharmaceutical activity for procedures

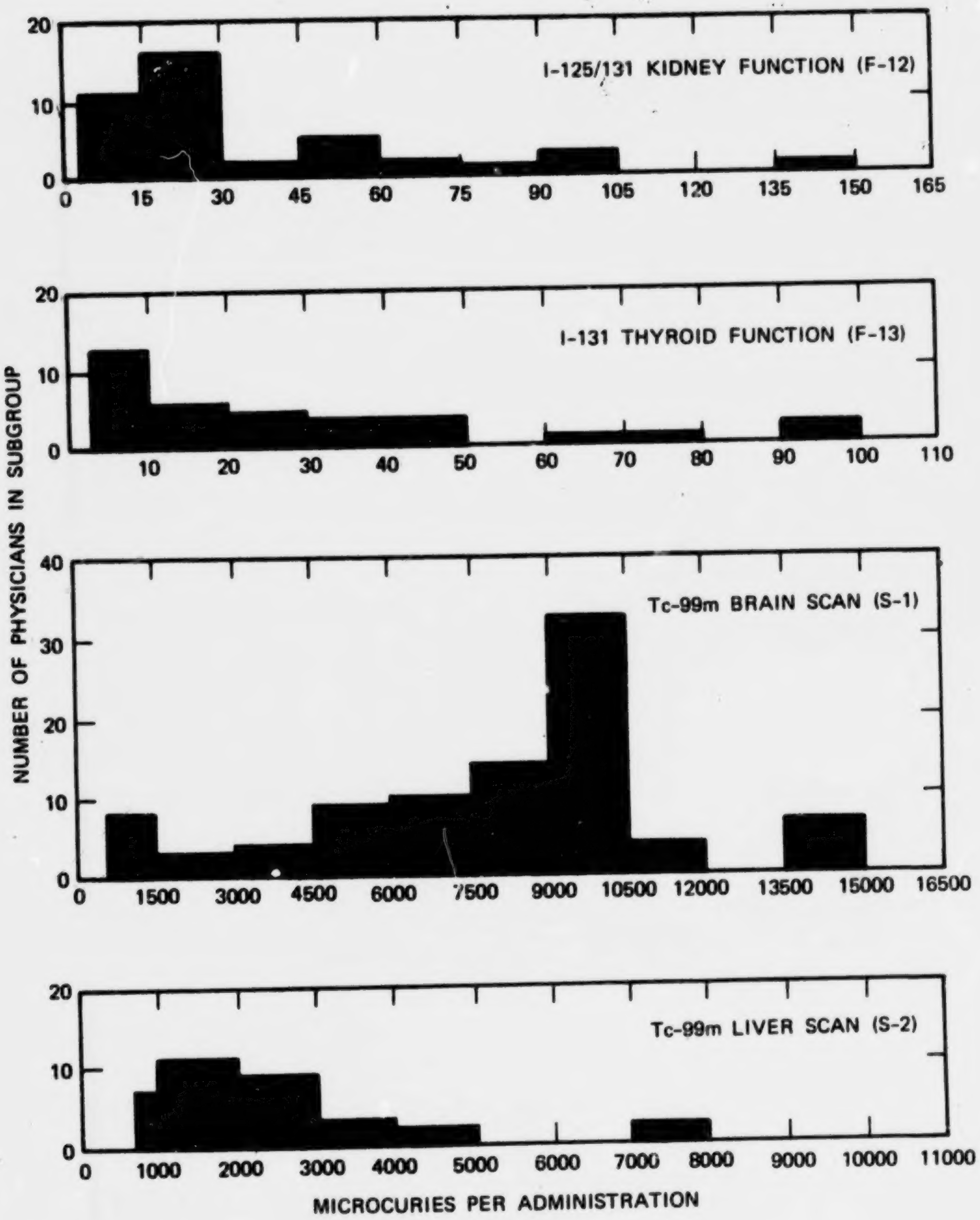

Figure 1 (continued)

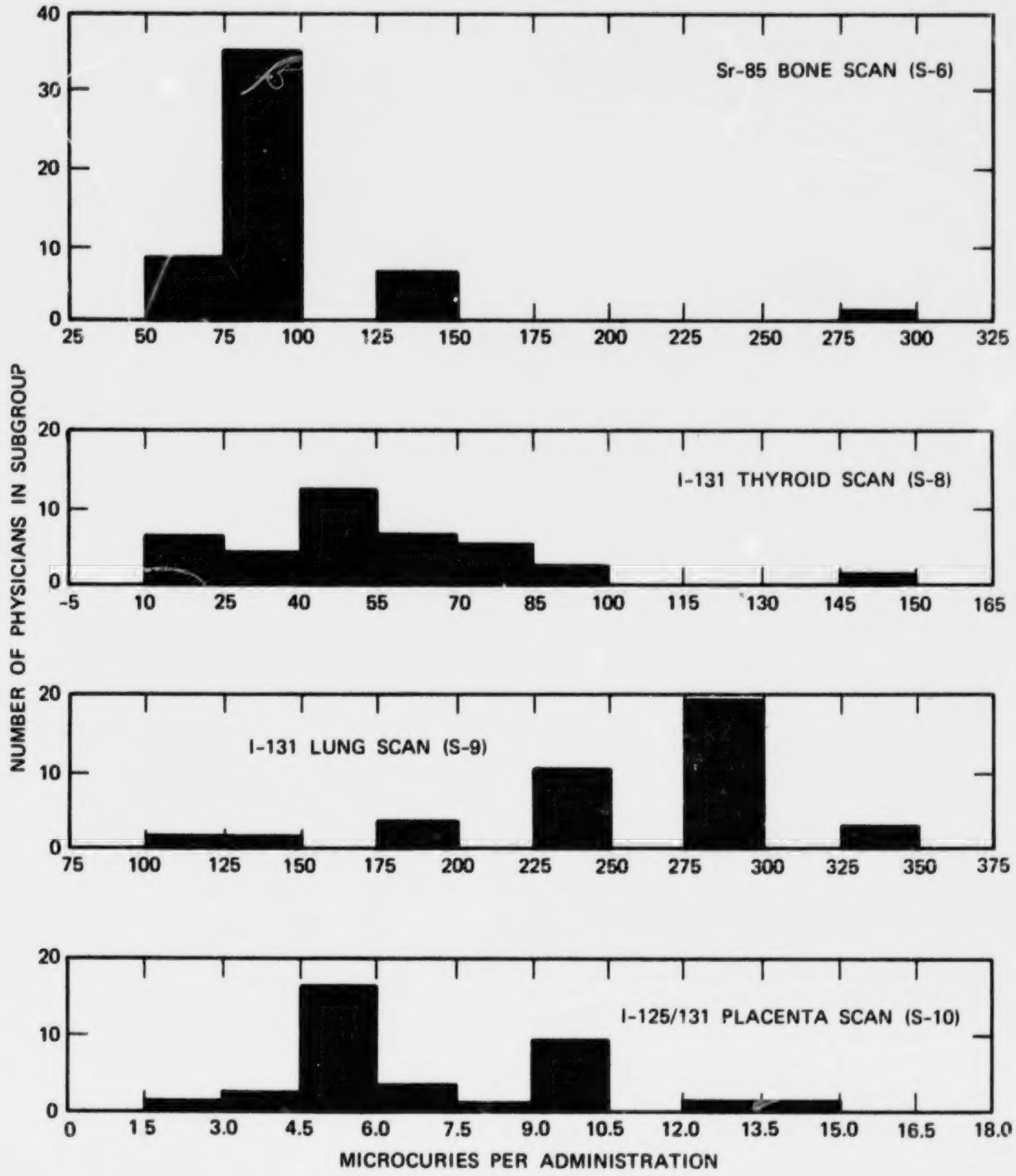

Figure 1 (continued)

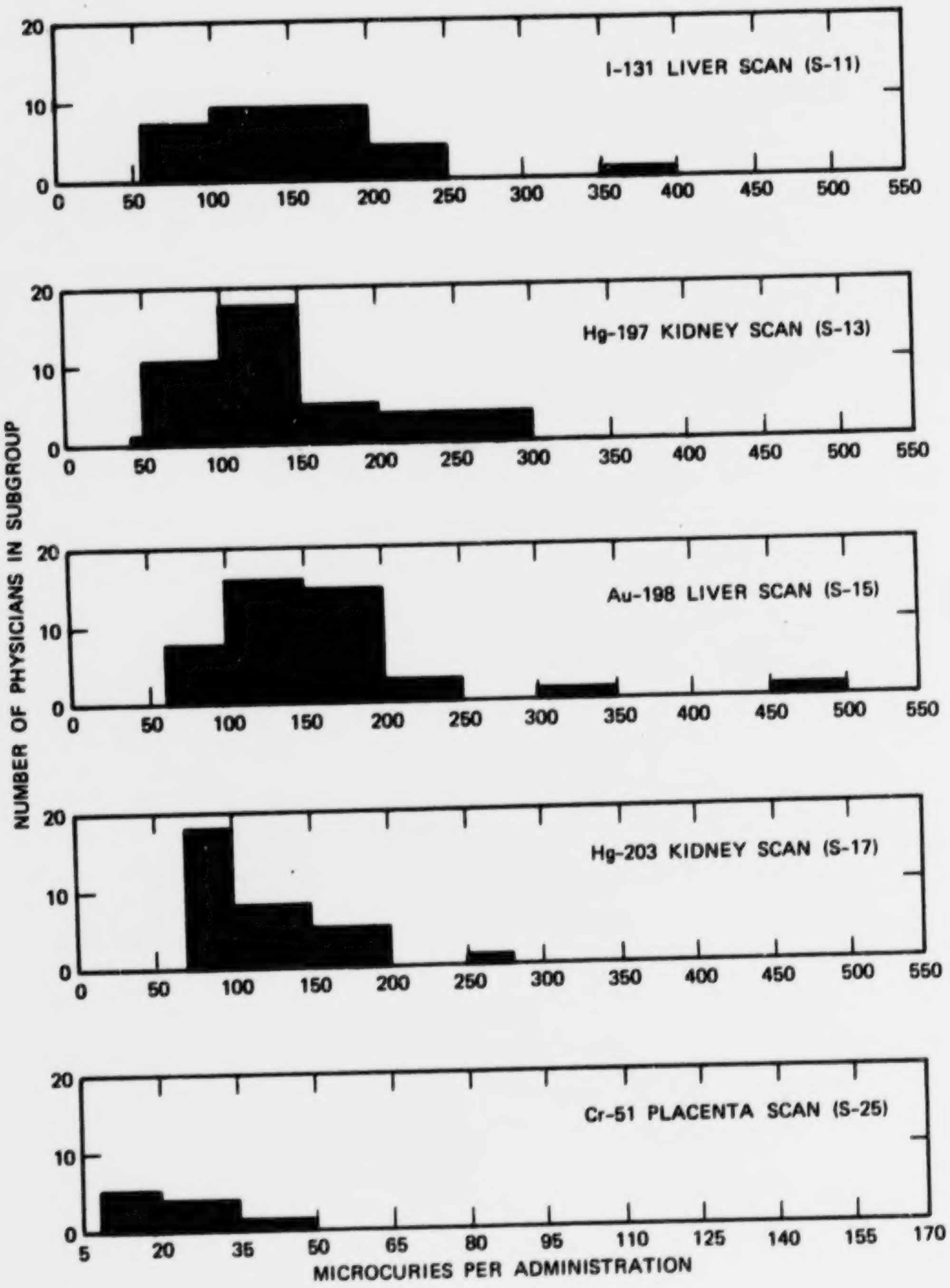

Figure 1 (concluded)

Table 33. Accelerated elimination practices

Procedure	Percent of Physicians Doing Procedure Accelerated Elimination No	Percent of Physicians Doing Procedure Accelerated Elimination Yes
Cr-51 Blood Volume (F-4)	84	16
Co-57 Vitamin B-12 (F-7)	74	26
Co-60 Vitamin B-12 (F-8)	86	14
I-125/131 Blood Volume (F-9)	92	8
I-125/131 Fat Absorption (F-11)	99	1
I-125/131 Kidney Function (F-12)	95	5
I-131 Thyroid Function (F-13)	100	--
Tc-99m Brain Scan (S-1)	98	2
TC-99m Liver Scan (S-2)	100	--
Sr-85 Bone Scan (S-6)	72	28
I-131 Thyroid Scan (S-8)	88	12
I-131 Lung Scan (S-9)	99	1
I-125/131 Placenta Scan (S-10)	97	3
I-131 Liver Scan (S-11)	100	--
I-131 Kidney Scan (S-12)	100	--
Hg-197 Kidney Scan (S-13)	96	4
Au-198 Liver Scan (S-15)	100	--
Hg-203 Kidney Scan (S-17)	92	8
Cr-51 Placenta Scan (S-25)	100	--

Table 34. Instrumentation calibration practices

Type of Instrumentation	Percent of Physicians Doing Any of the 23 Procedures Sampled							
	Using Instrumentation Type	Calibrate		Calibration Frequency				
		No	Yes	Each Use	Daily	Weekly	Monthly	Other
Rectilinear scanner	59.8	1.6	98.4	28.9	30.0	19.8	14.8	4.9
Imaging device	11.7	--	100.0	33.5	36.8	17.3	5.5	6.9
Scintillation probe	37.9	1.5	98.5	38.0	26.2	16.0	11.5	6.8
Geiger counter	11.1	--	100.0	25.2	20.8	13.1	22.8	18.1
Well counter	17.6	0.8	99.2	39.7	28.3	18.0	8.0	5.2

vitamin B-12 malabsorption and ^{85}Sr nitrate or chloride bone scanning, respectively. However, in both of these procedures elimination is accelerated in order to improve diagnostic effectiveness and not primarily to reduce patient radiation exposure. Data on the agents used for elimination were not obtained, but it is assumed that the practitioners reported on the use of stable vitamin B-12 to promote urinary excretion in the Schilling test, and the use of laxatives and enemas to reduce the background before scanning the area of the pelvis or lumbar spine. To determine whether accelerated elimination practices can or should be more widely used, each procedure would have to be examined in detail to determine the desirability of accelerated elimination in terms of patient comfort, radiation exposure, and the availability of a suitable agent.

Instrumentation Calibration

The radiation detection instrument calibration practices of the physicians engaged in diagnostic nuclear medicine are shown in Table 34 according to the type of instrument. Only a small percentage of practitioners do not calibrate their instruments. Generally speaking, the majority of practitioners calibrate with each use or at least daily. The fraction of those who calibrate at increasing intervals decreases with the length of the interval. Those indicated as "other" in the table calibrate at periods longer than a month.

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APPENDIXES

PHASE I

Appendix A

SURVEY QUESTIONNAIRE AND COVERING LETTER

STANFORD RESEARCH INSTITUTE
SRI

Location ____ Lic. No. ____

The United States Public Health Service, Division of Radiological Health, has contracted with Stanford Research Institute to design a continuing information system on the use of radioisotopes in medicine. This brief questionnaire is a first step toward developing this system. It is being sent to you as an AEC or state licensee using radioisotopes or radium.

The questionnaire asks for information on your individual practice; that is, the sum of all the diagnoses or treatments prescribed by you as a licensed individual physician, no matter where done, who requests, or who performs the actual administration. Your answers will be kept entirely confidential, although the findings from all the questionnaires will form the basis of a report to the Public Health Service.

The form is brief and easy to complete. Your prompt cooperation is earnestly requested.

Yours very truly,

James G. Roney, Jr.

James G. Roney, Jr., M.D., Ph.D.
Director, Health Planning Research

JGR/mac

INVENTORY OF THE USE OF ISOTOPES IN HUMANS

Please enter below your usage for One Year of radioactivity in your practice.

Make a BEST ESTIMATE if records are not conveniently available.

DIAGNOSTIC PROCEDURES

Check ALL Licensed To Perform	Isotope	Chemical Form	Procedure	Check if Ever Used	None in Past Year	If used in the past year:	
						No. of Patients	No. of Administrations
	Function studies -- patient-counting and sample-counting						
☐	I-131 or I-125	Labelled Tri-iodo-thyronine (T3)	In vitro T3 binding	☐			
☐	P-32	DFP	RBC survival				
☐	P-32	Sodium phosphate	Blood volume determination				
☐	Cr-51	Sodium chromate	Blood volume determination				
☐	Cr-51	Sodium chromate	RBC survival				
☐	Fe-59	Chloride or citrate	Iron turnover				
☐	Co-57	Labelled Vitamin B12	Vit. B12 malabsorption				
☐	Co-60	Labelled Vitamin B12	Vit. B12 malabsorption				
☐	I-131 or I-125	Labelled albumin	Blood volume determination				
☐	I-131 or I-125	Labelled albumin	Cardiac output				
☐	I-131 or I-125	Labelled fats f. acids	Fat malabsorption				
☐	I-131 or I-125	Sodium iodohippurate	Renal function				
☐	I-131	Sodium iodide	Thyroid uptake and excretion				
	Scanning studies						
☐	Tc-99m	Chelate or pertechnetate	Scanning of brain				
☐	Tc-99m	Colloid	Scanning of liver				
☐	Tc-99m	Colloid	Scanning of bone marrow				
☐	Cr-51	Heat-treated RBC	Scanning of spleen				
☐	Se-75	Selenomethionine	Scanning of pancreas				
☐	Sr-85	Nitrate or chloride	Scanning of bone				
☐	Sr-87m	Nitrate or chloride	Scanning of bone				
☐	I-131	Sodium iodide	Scanning of thyroid				
☐	I-131	Macroaggregates	Scanning of lungs				
☐	I-131 or I-125	Labelled albumin	Placental localization				
☐	I-131	Labelled rose bengal	Scanning of liver				
☐	I-131	Lab. renal func. comp.	Scanning of kidneys				
☐	Hg-197	Labelled mercurials	Scanning of kidneys				
☐	Hg-197	BMHP	Scanning of spleen				
☐	Au-198	Colloidal gold	Scanning of liver				
☐	Au-198	Colloidal gold	Scanning of bone marrow				
☐	Hg-203	Labelled mercurials	Scanning of kidneys				
	Diagnosis research						

Bureau of the Budget No. 68–662 OP
Expires 30 Sept. 1967

THERAPEUTIC PROCEDURES

Check ALL Licensed To Perform	Isotope	Chemical Form	Procedure	Check if Ever Used	None in Past Year	If used in the past year:	
						No. of Patients	No. of Administrations
	Therapy				☐		
☐	P–32	Soluble phosphate	Polycythemia vera	☐	☐		
☐	P–32	Soluble phosphate	Leukemia	☐	☐		
☐	P–32	Coll. chrom. phosphate	Malignant effusions	☐	☐		
☐	I–131	Sodium iodide	Hyperthyroidism	☐	☐		
☐	I–131	Sodium iodide	Ablation of thyroid	☐	☐		
☐	I–131	Sodium iodide	Thyroid cancer	☐	☐		
☐	I–131	Sodium iodide	Cardiac dysfunction	☐	☐		
☐	Au–198	Colloidal gold	Malignant effusions	☐	☐		
	Brachytherapy				☐		
☐	Co–60	Needles	Interstit. Rx of cancer	☐	☐		
☐	Co–60	Needles or seeds	Intracav. Rx of cancer	☐	☐		
☐	Sr–90	Eye applicator	Ophthalmic treatment	☐	☐		
☐	Rn–222	Seeds	Interstit. Rx of cancer	☐	☐		
☐	Ra–226	Needles	Interstit. Rx of cancer	☐	☐		
☐	Ra–226	Needles or seeds	Intracav. Rx of cancer	☐	☐		
☐	Ra–226	Naso-pharyngeal appl.	Intracav. Rx of cancer	☐	☐		
☐	Ra–226	Plaques	Dermatological treatment	☐	☐		
	Teletherapy				☐		
	ISOTOPE	MAKE & MODEL OF UNIT	CONDITION TREATED				
☐	Co–60			☐	☐		
☐	Cs–137			☐	☐		
	Therapy research				☐		

Please note any additional procedures, for which there is no space above, on the reverse side.

PLACE(S) OF PRACTICE

The first page gives the locations and licenses where our records show that you practice. Please list below or on the first page any additions or corrections.

LOCATION	LICENSE NO. (if known)	Addition	Correction
		☐	☐
		☐	☐
		☐	☐
		☐	☐

ADDITIONAL PROCEDURES

Isotope	Chemical Form	Procedure	No. of Patients	No. of Administrations
DIAGNOSTIC PROCEDURES				
THERAPEUTIC PROCEDURES				
RESEARCH				

Appendix B

MEDICAL PROCEDURES USING RADIONUCLIDES

This appendix gives the responses by procedures used. The categories of procedures are the same as those used in the questionnaire. However, write-ins have extended the numbers of procedures within each category considerably over those printed in the questionnaire. For example, 13 function study procedures were set up by the questionnaire, but the final list of function study procedures totals 50.

The system used for identifying the procedures is a letter followed by a sequence number of up to three digits. The code used for the procedure type is:

Code	
F	Function studies
S	Scanning studies
D	Diagnostic research procedures
O	Additional diagnostic research procedures (that is, a continuation of D)
T	Radiopharmaceutical therapy
B	Brachytherapy
C	Teletherapy
R	Therapy research procedures

Discontinuities occur in the sequence of numbers because some of the write-in procedures, as originally coded, were later determined to be the same as a previously recorded procedure. Procedures showing a number of patients but no administrations are in vitro procedures (F-1, F-25, and F-38).

		FUNCTION STUDIES	LICENSED	USED	UNUSED	PATIENTS	ADMIN.
F	1	I-125 OR I-131 IN-VITRO TRI-IODOTHYRONINE TEST (T3)	1380	1066	314	582807	0
F	2	P-32 DIISOPROPYLFLUOROPHOSPHATE RBC SURVIVAL	476	45	431	388	392
F	3	P-32 SODIUM PHOSPHATE BLOOD VOLUME DETERMINATION	494	32	462	799	804
F	4	CR-51 SODIUM CHROMATE BLOOD VOLUME DETERMINATION	1064	437	627	20460	22468
F	5	CR-51 SODIUM CHROMATE RBC SURVIVAL	1110	604	506	6187	6530
F	6	FE-59 CHLORIDE OR CITRATE IRON TURNOVER	836	287	549	3005	3139
F	7	CO-57 CYANOCOBALAMINE VITAMIN B-12 MALABSORPTION	952	582	370	23229	24996
F	8	CO-60 CYANOCOBALAMINE VITAMIN B-12 MALABSORPTION	1149	556	593	15443	16486
F	9	I-125 OR I-131 ALBUMIN BLOOD VOLUME DETERMINATION	1381	908	473	92107	101994
F	10	I-125 OR I-131 ALBUMIN CARDIAC OUTPUT	627	79	548	1375	1503
F	11	I-125 OR I-131 LABELED FATS AND F. ACIDS FAT MALABSORPTION	1054	505	549	6437	7742
F	12	I-125 OR I-131 SODIUM IODOHIPPURATE KIDNEY FUNCTION	817	388	429	30224	33245
F	13	I-131 SODIUM IODIDE THYROID UPTAKE AND EXCRETION	1527	1284	243	293602	301052
F	14	CR-51 SODIUM CHROMATE BLOOD LOSS STUDIES	28	27	1	391	439
F	15	I-131 SODIUM IODOHIPPURATE CEREBRAL CIRCULATION	2	2	0	212	252
F	16	I-125 OR I-131 ROSE BENGAL LIVER FUNCTION	33	23	10	592	1202
F	17	S-35 SODIUM SULFATE EXTRACELLULAR FLUID	3	2	1	33	41
F	18	I-131 SODIUM IODIDE CONVERSION RATIO	18	18	0	889	900
F	21	I-131 POLYVINYLPYRROLIDONE (PVP) PROTEIN LOSS	9	4	5	7	7
F	22	I-131 SODIUM IODOHIPPURATE CORONARY FLOW	2	1	1	31	31
F	25	FE-59 IN-VITRO IRON BINDING CAPACITY TEST	15	13	2	1261	0
F	27	HG-197 LABELED MERCURIALS KIDNEY FUNCTION	4	4	0	700	700
F	30	CR-51 ALBUMIN PROTEIN LOSS	25	14	11	45	47
F	31	BR-82 SODIUM BROMIDE EXTRACELLULAR FLUID	6	5	1	132	162
F	33	P-32 CHROMIC PHOSPHATE LIVER BLOOD FLOW	2	1	1	1	1
F	35	I-131 SODIUM IODIDE BUTANOL-EXTRACTABLE IODINE (BEI)	1	0	1	0	0
F	36	I-131 ALBUMIN PORTAL VEIN CIRCULATION	4	3	1	63	63
F	37	I-131 THYROXINE ELECTROPHORETIC THYROXINE-BINDING GLOBULIN	1	1	0	100	150
F	38	I-131 IN-VITRO THYROXINE TEST (T4)	3	2	1	1124	0
F	40	NA-22 OR NA-24 SODIUM CHLORIDE BODY SODIUM	10	7	3	119	576
F	41	K-42 POTASSIUM CHLORIDE BODY POTASSIUM	5	4	1	270	274
F	44	I-131 CHOLOGRAFIN LIVER FUNCTION	1	0	1	0	0
F	47	H-3 TRIATED WATER TOTAL BODY WATER	7	6	1	65	140
F	49	CO-57 CYANOCOBALAMINE KIDNEY FUNCTION	3	2	1	108	214
F	54	CR-51 SODIUM CHROMATE SPLEEN SEQUESTRATION	12	12	0	119	127
F	55	I-131 THYROXINE THYROXINE SURVIVAL	1	1	0	1	1
F	56	I-131 ALBUMIN LIVER FUNCTION	3	3	0	138	138
F	57	CA-47 CALCIUM CHLORIDE SKELETAL KINETICS	2	2	0	7	7
F	61	CU-64 CUPRIC ACETATE LIVER DEGENERATION	1	0	1	0	0
F	64	I-131 IODOPYRACET KIDNEY FUNCTION	1	1	0	5	5
F	67	HG-203 LABELED MERCURIALS KIDNEY FUNCTION	3	3	0	109	111
F	70	SR-85 NITRATE OR CITRATE SKELETAL KINETICS	1	1	0	5	5
F	76	I-131 IODOANTIPYRENE TOTAL BODY WATER	1	0	1	0	0
F	80	I-131 IODOHIPPURATE VASCULAR STUDIES	2	2	0	61	100
F	82	I-131 INSULIN PROTEIN BOUND INSULIN	3	3	0	226	226
F	83	I-131 ALBUMIN PERIPHERAL VASCULAR STUDIES	2	2	0	20	25
F	87	I-131 CHOLOGRAFIN CIRCULATION STUDIES	1	1	0	6	9
F	88	I-125 OR I-131 SODIUM IOTHALOMATE KIDNEY FUNCTION	1	1	0	100	100
F	91	NA-22 SODIUM CHLORIDE PERIPHERAL VASCULAR STUDIES	1	1	0	13	36
F	103	CA-47 CALCIUM CHLORIDE ORAL GI-ABSORPTION	1	1	0	30	36
		TOTAL	13085	6946	6139	1083046	526476

		SCANNING STUDIES	LICENSED	USED	UNUSED	PATIENTS	ADMIN.
S	1	TC-99M PERTECHNETATE BRAIN SCANNING	528	330	198	61423	63078
S	2	TC-99M COLLOID LIVER SCANNING	202	55	147	4895	4911
S	3	TC-99M COLLOID BONE MARROW SCANNING	157	14	143	145	146
S	4	CR-51 HEAT-TREATED RBC SPLEEN SCANNING	554	287	267	1605	1628
S	5	SE-75 SELENOMETHIONINE PANCREAS SCANNING	263	121	142	1607	1635
S	6	SR-85 NITRATE OR CHLORIDE BONE SCANNING	582	398	184	6109	6232
S	7	SR-87M NITRATE OR CHLORIDE BONE SCANNING	130	22	108	433	436
S	8	I-131 SODIUM IODIDE THYROID SCANNING	1092	908	184	141014	153089
S	9	I-131 ALBUMIN MACROAGGREGATES LUNG SCANNING	757	562	195	21487	22840
S	10	I-125 OR I-131 ALBUMIN PLACENTA SCANNING	619	325	294	3731	3921
S	11	I-131 ROSE BENGAL LIVER SCANNING	823	503	320	19388	19721
S	12	I-131 RENAL LABELED COMPOUNDS KIDNEY SCANNING	483	99	384	2058	2091
S	13	HG-197 LABELED MERCURIALS KIDNEY SCANNING	646	282	364	6773	6972
S	14	HG-197 MERCURIHYDROXYPPROPANE SPLEEN SCANNING	247	57	190	387	389
S	15	AU-198 COLLOID LIVER SCANNING	730	539	191	40322	41855
S	16	AU-198 COLLOID BONE MARROW SCANNING	226	12	214	127	127
S	17	HG-203 LABELED MERCURIALS KIDNEY SCANNING	787	543	244	16004	16223
S	18	HG-203 LABELED MERCURIALS BRAIN SCANNING	329	320	9	36981	37746
S	20	I-131 ALBUMIN HEART SCANNING	69	65	4	542	546
S	22	HG-197 LABELED MERCURIALS BRAIN SCANNING	162	145	17	17708	18489
S	25	CR-51 SODIUM CHROMATE PLACENTA SCANNING	14	13	1	163	163
S	26	I-131 ALBUMIN BRAIN SCANNING	37	34	3	3318	3511
S	27	I-131 SODIUM IODIPAMIDE HEART SCANNING	3	2	1	4	4
S	30	P-32 SODIUM PHOSPHATE EYE SCANNING	17	14	3	188	188
S	31	I-131 SODIUM IODOHIPPURATE HEART SCANNING	1	1	0	21	21
S	32	I-131 CHOLOGRAFIN HEART SCANNING	22	17	5	158	158
S	33	I-131 SODIUM IODIDE THYROID METASTASE SCANNING	12	11	1	111	114
S	35	I-131 ALBUMIN ABDOMEN SCANNING	2	2	0	5	5
S	36	SE-75 SELENOMETHIONINE PARATHYROID SCANNING	24	22	2	86	86
S	37	AS-74 SODIUM ARSENATE BRAIN SCANNING	2	1	1	15	15
S	39	HG-203 MERCURIHYDROXYPROPANE SPLEEN SCANNING	6	6	0	13	13
S	40	TC-99M ALBUMIN PLACENTA SCANNING	12	12	0	249	254
S	44	I-131 ALBUMIN MICROAGGREGATES LIVER SCANNING	9	4	5	282	311
S	45	CS-131 CESIUM CHLORIDE HEART SCANNING	4	3	1	196	196
S	46	AU-198 COLLOID LYMPH NODE SCANNING	2	1	1	27	27
S	48	TC-99M ALBUMIN HEART SCANNING	4	4	0	180	180
S	51	P-32 SODIUM PHOSPHATE CHOROIDAL MELANOM SCANNING	1	1	0	1	1
S	52	TC-99M PERTECHNETATE VASCULAR SYSTEM SCANNING	5	5	0	71	71
S	54	I-125 SODIUM IODIDE THYROID SCANNING	5	4	1	1350	1354
S	55	TC-99M IRON COMPLEX KIDNEY SCANNING	1	1	0	96	96
S	56	TC-99M PERTECHNETATE THYROID SCANNING	5	5	0	258	259
S	65	TC-99M COLLOID SPLEEN SCANNING	2	2	0	51	51
S	66	TC-99M PERTECHNETATE SALIVARY GLAND SCANNING	4	4	0	19	21
S	74	AU-198 COLLOID SPLEEN SCANNING	2	2	0	12	12
S	78	I-131 ALBUMIN HAND AND WRIST SCANNING	1	1	0	1	1
S	82	TC-99M COLLOID LUNG SCANNING	1	1	0	200	200
S	84	P-32 SODIUM PHOSPHATE BONE SCANNING	1	0	1	0	0
S	86	P-32 SODIUM PHOSPHATE GI-TUMOR SCANNING	1	1	0	70	70
S	87	SE-75 SELENOMETHIONINE BONE SCANNING	1	1	0	2	2
		TOTAL	9587	5762	3825	389886	409461

		DIAGNOSTIC RESEARCH STUDIES	LICENSED	USED	UNUSED	PATIENTS	ADMIN.
D	1	I-131 IN-VITRO TRI-IODOTHYRONINE TEST (T3)	2	2	0	35	59
D	2	CR-51 SODIUM CHROMATE RBC SURVIVAL	7	5	2	50	50
D	3	SE-75 SODIUM SELENATE TUMOR LOCALIZATION	5	5	0	132	192
D	4	S-35 SODIUM SULFATE TISSUE CULTURE	4	3	1	96	165
D	5	C-14 CHOLESTEROL METABOLIC STUDIES	7	7	0	374	408
D	6	H-3 CHOLESTEROL METABOLIC STUDIES	5	5	0	336	346
D	7	I-131 LABELED FATS FAT MALABSORPTION	1	1	0	4	4
D	8	KR-85 SALINE SOLUTION CARDIAC OUTPUT	12	7	5	282	289
D	9	I-131 INSULIN IMMUNO-ASSAY	7	2	5	54	54
D	10	I-131 LABELED HORMONES METABOLIC STUDIES	4	3	1	2034	2034
D	12	I-131 ALBUMIN BLOOD VOLUME DETERMINATION	8	8	0	284	752
D	13	KR-85 GAS BRAIN BLOOD FLOW	4	4	0	133	298
D	14	XE-133 GAS MUSCLE BLOOD FLOW	6	6	0	125	290
D	15	I-125 THYROXINE IN-VITRO TEST	6	3	3	44	48
D	16	C-14 LABELED DIURETIC COMPOUNDS DRUG DISPOSITION	2	1	1	50	50
D	17	MG-28 MAGNESIUM SULFATE METABOLIC STUDIES	2	1	1	20	20
D	18	H-3 DIISOPROPYLFLUOROPHOSPHATE PLATELET SURVIVAL	1	1	0	8	8
D	19	H-3 TRITIATED WATER TOTAL BODY WATER	12	8	4	112	125
D	20	H-3 ALDOSTERONE ADRENAL SECRETION RATE	12	12	0	223	324
D	21	C-14 UREA METABOLIC STUDIES	3	2	1	27	29
D	22	I-131 THYROXINE METABOLIC STUDIES	12	11	1	630	645
D	23	I-131 ALBUMIN MACROAGGREGATES PELVIS SCANNING	1	1	0	5	6
D	24	TC-99M PERTECHNETATE PAROTID GLAND SCANNING	2	1	1	1	1
D	25	FE-55 CHLORIDE OR CITRATE IRON ABSORPTION	3	2	1	8	8
D	26	CA-47 CALCIUM CHLORIDE METABOLIC STUDIES	13	10	3	193	218
D	27	P-32 IN-VITRO PRODUCTION OF ATP	2	0	2	0	0
D	28	C-14 GLYCINE METABOLIC STUDIES	6	4	2	14	14
D	29	H-3 THYMIDINE AUTORADIOGRAPHY	6	3	3	280	280
D	30	CA-47 CALCIUM CHLORIDE GI-BLOOD LOSS	1	1	0	53	53
D	31	BA-137M CHLORIDE METABOLIC STUDIES	1	1	0	15	40
D	32	BA-137M CHLORIDE METABOLIC STUDIES	1	1	0	20	45
D	33	H-3 METHOTREXATE METABOLIC STUDIES	2	2	0	16	16
D	34	I-131 AMINOPTERIN METABOLIC STUDIES	3	2	1	16	18
D	35	I-131 ALBUMIN METABOLIC STUDIES	4	3	1	17	22
D	36	CR-51 ALBUMIN GI-BLOOD LOSS	5	5	0	20	21
D	37	C-14 CORTISOL PLASMA CLEARANCE	10	8	2	189	227
D	38	I-131 IODINE THYROID CONTROL OF MELANIN	1	0	1	0	0
D	39	TC-99M ALBUMIN PLACENTA SCANNING	3	3	0	55	55
D	40	I-125 LABELED PROTEIN REC SENSITIZATION	3	3	0	12	12
D	42	C-14 GLUCOSE METABOLIC STUDIES	7	6	1	52	91
D	43	C-14 GLUCOSE IN-VITRO STUDIES	1	0	1	0	0
D	44	P-32 SODIUM PHOSPHATE IN-VITRO STUDIES	1	0	1	0	0
D	45	H-3 TRIGLYCEROL METABOLIC STUDIES	1	0	1	0	0
D	46	XE-133 SALINE SOLUTION BLOOD FLOW	6	5	1	193	313
D	47	H-3 HYDROCHLOROTHIAZIDE METABOLIC STUDIES	2	2	0	11	11
D	48	NA-22 SODIUM CHLORIDE BODY SODIUM	7	6	1	76	96
D	49	K-42 POTASSIUM CHLORIDE BODY POTASSIUM	8	7	1	98	129
D	50	I-131 FIBRINOGEN IN-VITRO STUDIES	1	0	1	0	0
D	51	I-131 LABELED ACTH IN-VITRO STUDIES	2	1	1	1	1
D	52	CR-51 CHROMATE SKIN APPLICATION	1	1	0	20	60
D	53	C-14 BILE ACIDS METABOLIC STUDIES	3	3	0	27	37
D	54	C-14 PALMITIC ACID SKIN SURFACE LIPIDS	9	9	0	128	176
D	56	C-14 STANINE METABOLIC STUDIES	1	1	0	20	40
D	57	C-14 GLYCEROL METABOLIC STUDIES	1	1	0	20	40
D	58	C-14 LACTIC ACID METABOLIC STUDIES	1	1	0	20	40

	DIAGNOSTIC RESEARCH STUDIES	LICENSED	USED	UNUSED	PATIENTS	ADMIN.
D 59	H-3 LABELED STEROIDS PLACENTAL PERFUSION	3	3	0	23	23
D 60	C-14 LABELED STEROIDS PLACENTAL PERFUSION	2	2	0	7	7
D 61	C-14 TRYPTOPHAN METABOLIC STUDIES	2	2	0	8	8
D 62	C-14 KYMURENIC ACID METABOLIC STUDIES	1	1	0	5	5
D 63	NA-22 SODIUM CHLORIDE VASCULAR STUDIES	1	1	0	20	20
D 64	C-14 AMPHOTERICIN-B CEREBROSPINAL FLUID STUDIES	1	0	1	0	0
D 65	C-14 INULIN CEREBROSPINAL FLUID STUDIES	3	2	1	3	4
D 66	CR-51 CHROMIUM CHLORIDE PROTEIN LOSS	5	5	0	90	110
D 67	I-131 POLYVINYLPYRROLIDONE (PVP) PROTEIN LOSS	2	1	1	10	10
D 68	CR-51 SODIUM CHROMATE RBC SURVIVAL	2	2	0	130	130
D 69	I-131 ALBUMIN HEMAGGLUTINATION	1	0	1	0	0
D 70	H-3 ESTRADIOL HORMONE ASSAY	4	4	0	108	108
D 71	SE-75 SELENOMETHIONINE PARATHYROID SCANNING	4	4	0	15	15
D 72	I-131 TRI-IODOTHYRONINE ORGAN SCANNING	1	0	1	0	0
D 73	C-14 CARBON DIOXIDE BREATH ANALYSIS	1	0	1	0	0
D 74	I-131 MICROAGGREGATED ALBUMIN R.E.S. FUNCTION	1	1	0	5	5
D 75	I-131 SODIUM IODIDE PLASMA IMMUNO-ASSAY	2	1	1	100	100
D 76	C-14 DOPAMINE INFUSION STUDIES	1	1	0	5	5
D 77	H-3 DOPAMINE INFUSION STUDIES	1	1	0	5	5
D 78	C-14 PALMITATE FAT MALABSORPTION	1	1	0	50	50
D 79	C-14 ALDOSTERONE HORMONE ASSAY	1	1	0	9	9
D 80	FE-59 FERRIC CHLORIDE IRON ADSORPTION	4	4	0	219	274
D 81	H-3 INULIN GLOMERULAR FILTRATION RATE	1	1	0	5	5
D 82	C-14 LINOLEIC ACID METABOLIC STUDIES	1	1	0	3	3
D 83	TC-99M PERTECHNETATE CORONARY BLOOD FLOW	1	1	0	8	8
D 84	C-14 SEROTONIN IN-VITRO INCUBATION STUDIES	1	0	1	0	0
D 85	CA-47 CHLORIDE ORAL ABSORPTION	2	2	0	51	51
D 86	C-14 CORTICOSTERONE SECRETION RATE	1	1	0	10	20
D 87	H-3 DESOXYCORTICOSTERONE SECRETION RATE	3	3	0	50	80
D 88	C-14 PROLINE IN-VITRO STUDIES	1	1	0	6	35
D 89	I-131 IODOHIPPURATE KIDNEY SCANNING	1	0	1	0	0
D 90	H-3 NOREPINEPHRINE METABOLIC STUDIES	1	1	0	3	3
D 91	H-3 CORTISOL SECRETION RATE	3	3	0	43	73
D 92	H-3 CORTICOSTERONE SECRETION RATE	1	1	0	2	2
D 93	P-32 SODIUM PHOSPHATE FEMORAL HEAD VISIBILITY	1	0	1	0	0
D 95	CO-60 CYANOCOBALAMINE MALABSORPTION	1	1	0	15	15
D 96	I-125 INTRINSIC FACTOR METABOLIC STUDIES	2	2	0	65	65
D 97	CO-57 CYANOCOBALAMINE MALABSORPTION	5	5	0	61	65
D 98	P-32 SODIUM PHOSPHATE BRAIN METOBOLIC STUDIES	1	1	0	10	10
D 99	CA-45 CALCIUM CHLORIDE SKELETAL KINETICS	2	2	0	23	31
D 100	SR-85 STRONTIUM CHLORIDE SKELETAL KINETICS	3	2	1	113	113
D 102	I-131 BOVINE BILE TUMOR SCANNING	1	1	0	6	6
D 103	K-40 WHOLE BODY COUNTING	1	1	0	5	10
D 104	C-14 GLYCINE BILIRUBIN STUDIES	1	1	0	1	1
D 105	I-131 LABELED HORMONES IN-VITRO STUDIES	2	1	1	77	77
D 106	CR-51 TETRACYCLINE METABOLIC STUDIES	1	1	0	4	4
D 107	I-125 IOTHALAMATE KIDNEY FUNCTION	1	1	0	75	100
D 108	I-131 CHOLOGRAFIN PERICARDIAL EFFUSION	2	2	0	13	13
D 109	C-14 LABELED STEROIDS METABOLIC STUDIES	6	6	0	302	352
D 110	H-3 FOLATE FOLIC ACID ABSORPTION	1	1	0	13	13
D 111	H-3 PROGESTERONE METABOLIC STUDIES	1	1	0	23	23
D 112	H-3 AND C-14 ALDOSTERONE METABOLIC STUDIES	4	4	0	922	922
D 113	I-131 ALBUMIN MACROAGGREGATES ARM AND LEG STUDIES	1	1	0	43	43
D 114	CR-51 SODIUM CHROMATE DUODENAL DRAINAGE	1	1	0	50	50
D 115	CA-47 CALCIUM CHLORIDE SKELETAL KINETICS	1	1	0	24	24

	DIAGNOSTIC RESEARCH STUDIES	LICENSED	USED	UNUSED	PATIENTS	ADMIN.
D 116	KR-85 SALINE SOLUTION KIDNEY SCANNING	1	1	0	8	8
D 117	H-3 THYMIDINE INFUSION STUDIES	1	1	0	4	4
D 118	I-131 ALBUMIN JOINT STUDIES	1	1	0	20	22
D 119	AU-198 COLLOID JOINT STUDIES	3	3	0	29	30
D 120	S-35 LABELED DMSO SKIN ABSORPTION	1	1	0	2	2
D 121	I-125 POLYVINYLPYRROLIDONE PROTEIN LOSS	1	0	1	0	0
D 122	H-3 PALMITATE METABOLIC STUDIES	1	1	0	12	24
D 123	AU-198 COLLOID LIVER FUNCTION	1	0	1	0	0
D 124	H-3 THYMIDINE IN-VITRO STUDIES	4	3	1	144	144
D 125	H-3 LABELED HORMONES METABOLIC STUDIES	1	1	0	5	5
D 126	I-131 ALBUMIN MACROAGGREGATES LUNG SCANNING	5	5	0	218	256
D 127	I-125 ALBUMIN CARDIAC OUTPUT	2	2	0	17	55
D 128	C-14 SODIUM GLYOXALITE METABOLIC STUDIES	1	1	0	3	6
D 129	C-14 VITAMIN-A METABOLIC STUDIES	1	1	0	3	3
D 130	C-14 CAROTENE METABOLIC STUDIES	1	1	0	3	3
D 131	I-131 IODOHIPPURATE CIRCULATION STUDIES	2	2	0	110	112
D 132	I-125 OR I-131 LABELED FATS FAT MALABSORPTION	1	1	0	10	10
D 133	I-131 NEOGRAFIN ABSORPTION STUDIES	1	1	0	10	10
D 134	I-125 IODOHIPPURATE KIDNEY FUNCTION	1	1	0	6	10
D 135	C-14 INDOMETHACIN KIDNEY FUNCTION	1	1	0	3	5
D 137	TC-99M IRON COMPLEX KIDNEY SCANNING	2	2	0	8	8
D 138	GA-68 HYDROXIDE LUNG AND LIVER SCANNING	1	1	0	3	3
D 139	I-131 SODIUM IODIDE AUTORADIOGRAPHY	3	3	0	33	33
D 140	C-14 SODIUM ACETATE IN-VITRO SYNTHESIS	2	1	1	1	1
D 141	C-14 HYDROCORTISONE SECRETION RATE	2	1	1	20	20
D 142	SE-75 SELENOMETHIONINE LYMPHOMA SCANNING	3	3	0	62	62
D 144	H-3 HYDROCORTISONE SECRETION RATE	1	0	1	0	0
D 146	I-131 LABELED ANTIBODIES TUMOR LOCALIZATION	1	1	0	130	130
D 147	I-131 FIBRINOGEN TUMOR LOCALIZATION	2	2	0	45	45
D 148	I-131 THYROXINE T-4 BINDING	1	0	1	0	0
D 149	P-32 SODIUM PHOSPHATE IN-VITRO STUDIES	2	0	2	0	0
D 150	I-125 OR I-131 SODIUM IODIDE IN-VITRO STUDIES	1	1	0	12	12
D 152	I-125 LABELED PROTEINS METABOLIC STUDIES	1	0	1	0	0
D 153	C-14 TRIOLEIN FAT MALABSORPTION	1	0	1	0	0
D 154	SE-75 SELENOMETHIONINE THYMUS SCANNING	1	1	0	11	11
D 155	TC-99M PERTECHNETATE CEREBRAL BLOOD FLOW	1	1	0	100	100
D 158	I-125 INSULIN IN-VITRO STUDIES	2	2	0	51	51
D 159	C-14 GLUCOSE-PYRUVATE CARBON DIOXIDE PRODUCTION	1	1	0	5	20
D 160	C-14 HYDROXYKYNURENINE ACID TUMOR LOCALIZATION	1	1	0	10	10
D 161	C-14 HYDROXYANTHRANILIC ACID TUMOR LOCALIZATION	1	1	0	10	10
D 162	C-14 ANTHRANILIC ACID TUMOR LOCALIZATION	1	1	0	10	10
D 163	I-131 SODIUM IODINE THYROID DYSFUNCTION	1	1	0	10	10
D 166	C-14 HCO3 METABOLIC STUDIES	1	1	0	10	10
D 167	C-14 CHOLESTEROL METABOLIC STUDIES	1	1	0	4	4
D 168	H-3 CHLORPHENIRAMINE METABOLIC STUDIES	1	1	0	9	27
D 169	H-3 METHOTREXATE AUTORADIOGRAPHS	1	1	0	11	17
D 170	H-3 STREPTONIGRIN AUTORADIOGRAPHS	1	1	0	4	5
D 172	C-14 ETHANOL METABOLIC STUDIES	1	1	0	1	1
D 173	C-14 PHENYLALINE SECRETION RATE	1	1	0	2	2
D 174	I-125 OR I-131 IODOPYRACET KIDNEY FUNCTION	1	1	0	30	30
D 176	I-131 AMINOPYRINE CORONARY BLOOD FLOW	3	2	1	19	49
D 177	I-131 HUMAN F.S.H. RADIOIMMUNO ASSAY	1	1	0	200	200
D 178	I-125 HUMAN F.S.H. BIOLOGICAL HALF LIFE	2	2	0	4	4
D 179	I-131 HUMAN L.S.H. RADIOIMMUNO ASSAY	1	0	1	0	0
D 180	H-3 GLYCEROL METABOLIC STUDIES	1	1	0	10	20

	DIAGNOSTIC RESEARCH STUDIES	LICENSED	USED	UNUSED	PATIENTS	ADMIN.
D 181	I-125 ALBUMIN PEPSIN DETERMINATION	1	1	0	100	100
D 182	CO-57 CYANOCOBALAMINE PARATHYROID LOCALIZATION	1	1	0	3	3
D 184	I-131 ALBUMIN CISTERNOGRAMS	4	4	0	21	23
D 186	C-14 GLYCINE HEMOGLOBIN UPTAKE	1	1	0	10	20
D 187	C-14 HISTIDINE HEMOGLOBIN UPTAKE	1	1	0	5	10
D 188	I-125 OR I-131 GAMMA GLOBULIN METABOLIC STUDIES	3	2	1	3	4
D 189	I-125 OR I-131 MACROGLOBULIN METABOLIC STUDIES	1	0	1	0	0
D 190	H-3 EPINEPHRINE METABOLIC STUDIES	1	1	0	15	15
D 191	FE-59 FERRIC SULFATE IRON ABSORPTION	1	0	1	0	0
D 192	FE-55 FERRIC CHLORIDE IRON ABSORPTION	1	0	1	0	0
D 193	KR-85 GAS PULMONARY FUNCTION	1	1	0	22	25
D 194	I-131 SODIUM IODIDE DAILY CONVERSION	1	1	0	20	20
D 195	HG-203 LABELED MERCURIALS TONSIL SCANNING	1	1	0	2	2
D 196	FE-59 CITRATE IRON ABSORPTION	1	1	0	3	3
D 197	TC-99M PERTECHNETATE THYROID SCANNING	2	2	0	55	55
D 198	C-14 ESTRADIOL SECRETION RATE	1	1	0	2	2

	ADDITIONAL DIAGNOSTIC RESEARCH STUDIES	LICENSED	USED	UNUSED	PATIENTS	ADMIN.
O 1	CA-47 CALCIUM NITRATE ABSORPTION STUDIES	2	2	0	8	8
O 2	NA-24 SODIUM CHLORIDE ABSORPTION STUDIES	2	2	0	92	103
O 3	K-42 POTASSIUM CHLORIDE ABSORPTION STUDIES	2	2	0	57	74
O 4	NA-22 SODIUM CHLORIDE ABSORPTION STUDIES	2	2	0	37	47
O 5	H-3 TRITIUM GI-SORPTION	2	2	0	54	61
O 6	I-125 ALBUMIN METABOLIC STUDIES	2	2	0	11	11
O 7	CR-51 ALBUMIN METABOLIC STUDIES	1	1	0	10	10
O 8	CS-131 CESIUM ACETATE MYOCARDIUM SCANNING	2	2	0	22	22
O 9	H-3 DIGOXIN METABOLIC STUDIES	2	2	0	86	86
O 10	SE-75 SELENOMETHIONINE BLOOD TURNOVER	2	1	1	20	20
O 11	SE-75 SELENOMETHIONINE PROTEIN TURNOVER	2	1	1	18	20
O 12	SR-85 STRONTIUM NITRATE BONE UPTAKE	1	1	0	12	12
O 13	CA-47 DELOMIDE BONE UPTAKE	1	1	0	6	6
O 14	I-131 THYROXINE T-4 BINDING	1	1	0	150	150
O 16	CS-131 CHLORIDE AND ACETATE PANCREAS SCANNING	1	1	0	8	8
O 17	I-131 AND HG-197 DUAL STUDIES	1	1	0	150	170
O 18	H-3 URIDINE IN-VITRO STUDIES	1	1	0	140	140
O 19	H-3 DTTP-DTR-DTMP IN-VITRO STUDIES	1	1	0	170	170
O 20	C-14 FORMATE IN-VITRO STUDIES	1	1	0	5	5
O 26	H-3 TESTOSTERONE METABOLIC STUDIES	1	1	0	1	1
O 27	I-131 SODIUM IODIDE PBI STUDIES	1	1	0	8	8
O 28	I-131 SODIUM IODIDE TSH STUDIES	2	2	0	29	29
O 29	I-131 SODIUM IODIDE T-3 STIMULATION	1	1	0	6	6
O 30	C-14 LABELED AMINO ACIDS METABOLIC STUDIES	2	1	1	20	50
O 31	H-3 TRITIUM METABOLIC STUDIES	2	2	0	17	17
O 33	CR-51 SODIUM CHROMATE BLOOD FLOW	4	4	0	19	24
O 34	I-125 ALBUMIN VASCULAR VOLUME	1	1	0	10	15
O 35	NA-24 SODIUM CARBONATE SODIUM SPACE	1	1	0	10	10
O 38	CR-51 SODIUM CHROMATE GI-BLOOD LOSS	4	3	1	7	7
O 39	CR-51 ALBUMIN GI-BLOOD LOSS	1	1	0	4	4
O 40	H-3 LABELED STEROIDS METABOLIC STUDIES	2	2	0	203	206
O 47	C-14 LABELED DRUGS METABOLIC STUDIES	1	1	0	9	9
O 48	I-125 AND CR-51 IODIDE AND CHROMATE DUAL BLOOD VOLUME	1	0	1	0	0
O 49	C-14 GLUCOSE METABOLIC STUDIES	1	1	0	1	1

NOT REPRODUCIBLE

		ADDITIONAL DIAGNOSTIC RESEARCH STUDIES	LICENSED	USED	UNUSED	PATIENTS	ADMIN.
0	50	C-14 PALMITATE METABOLIC STUDIES	1	1	0	1	1
0	53	TC-99M PERTECHNETATE VASCULAR STUDIES	1	1	0	50	60
0	54	HG-197 LABELED MERCURIALS BRAIN SCANNING	1	1	0	15	15
0	55	S-35 SODIUM SULFATE METABOLIC STUDIES	2	1	1	4	4
0	56	H-3 METHIONINE METABOLIC STUDIES	1	1	0	4	4
0	58	CU-64 ACETATE ABSORPTION STUDIES	1	1	0	12	18
0	59	CU-64 ACETATE METABOLIC STUDIES	1	1	0	23	24
0	60	ZR-95 OXALATE GI-BLOOD LOSS	2	1	1	25	25
0	61	C-14 CYTOXAN PERFUSION STUDIES	1	0	1	0	0
0	62	I-132 HYDROXIDE THYROID FUNCTION	2	1	1	20	100
0	63	CR-51 SODIUM CHROMATE CARDIAC OUTPUT	1	1	0	2	2
0	64	SE-75 SELENOMETHIONINE KIDNEY BLOOD FLOW	4	4	0	29	29
0	65	P-32 SODIUM PHOSPHATE BRAIN CALCIUM DURING SURGERY	1	1	0	20	20
0	67	I-131 INSULIN BLOOD VOLUME DETERMINATION	1	0	1	0	0
0	68	CR-51 SODIUM CHROMATE PERFUSION STUDIES	1	1	0	7	7
0	69	NA-22 SODIUM CHLORIDE CARDIAC OUTPUT	2	0	2	0	0
0	71	F-18 FLUORIDE BONE SCANNING	6	6	0	114	114
0	72	FE-59 CITRATE THORACIC SCANNING	1	0	1	0	0
0	73	I-131 ROSE BENGAL BLOOD POOL SCANNING	2	2	0	7	7
0	74	TC-99M ALBUMIN HEART SCANNING	5	5	0	200	200
0	75	I-131 ALBUMIN CSF FISTULA SCANNING	1	1	0	1	1
0	76	TC-99M ALBUMIN LUNG SCANNING	5	5	0	313	313
0	77	FE-52 CITRATE BONE MARROW SCANNING	1	1	0	2	2
0	78	IN-113M IRON COMPLEX LUNG SCANNING	4	4	0	211	211
0	79	CR-51 HEAT TREATED RBC LIVER SCANNING	1	1	0	1	1
0	80	I-131 ROSE BENGAL HEART SCANNING	2	2	0	8	8
0	81	I-131 METHYL IODIDE LIVER SCANNING	1	1	0	5	5
0	82	I-131 POLYVINYLPYRROLIDONE (PVP) BRAIN SCANNING	1	1	0	1	1
0	83	I-131 ETHIODOL LYMPHATIC SCANNING	1	1	0	80	80
0	84	AU-198 COLLOID LUNG SCANNING	1	1	0	15	15
0	85	I-123 SODIUM IODIDE THYROID SCANNING	1	1	0	2	2
0	86	TC-99M PERTECHNETATE ORGAN SCANNING	1	1	0	6	16
0	88	H-3 THYMIDINE BONE FRACTURES	1	1	0	2	2
0	89	I-131 ALBUMIN JOINT SCANNING	1	1	0	13	15
0	90	TC-99M ALBUMIN JOINT SCANNING	1	1	0	2	2
0	91	I-131 IODIPAMIDE JOINT SCANNING	1	1	0	53	59
0	92	TC-99M PERTECHNETATE JOINT SCANNING	1	1	0	9	9
0	93	AG-111 APPLICATION NOT REPORTED	1	0	1	0	0
0	94	FE-55 NITRATE OR CITRATE IRON ABSORPTION STUDIES	2	2	0	10	10
0	95	TC-99M PERTECHNETATE CIRCULATION TIME	1	1	0	2	2
0	97	CR-51 HEPATIC UPTAKE	1	1	0	10	10
0	99	P-32 PHOSPHATE INTRA-OCULAR TUMOR DETECTION	2	2	0	62	62
		TOTAL	565	471	19	13905	16227

		RADIOPHARMCEUTICAL THERAPY	LICENSED	USED	UNUSED	PATIENTS	ADMIN.
T	1	P-32 SODIUM PHOSPHATE POLYCYTHEMIA VERA	1086	581	505	2522	3405
T	2	P-32 SODIUM PHOSPHATE LEUKEMIA	819	132	687	562	933
T	3	P-32 COLLOID MALIGNANT EFFUSIONS	724	316	408	1860	2033
T	4	I-131 SODIUM IODIDE HYPERTHYROIDISM	1229	1042	187	18351	20717
T	5	I-131 SODIUM IODIDE THYROID ABLATION	869	295	574	1959	2316
T	6	I-131 SODIUM IODIDE THYROID CANCER	907	334	573	1499	1768
T	7	I-131 SODIUM IODIDE CARDIAC DYSFUNCTION	825	224	601	801	927
T	8	AU-198 COLLOID MALIGNANT EFFUSIONS	681	152	529	680	732
T	9	P-32 POLYMETAPHOSPHATE OSSEOUS METASTASES	50	41	9	299	701
T	10	AU-198 COLLOID PROSTATE CARCINOMA	3	3	0	7	8
T	12	P-32 SODIUM PHOSPHATE PROSTATE CARCINOMA	12	11	1	41	98
T	14	AU-198 SILVER COATED BRONCHIOGENIC TREATMENT	1	0	1	0	0
T	16	P-32 COLLOIDAL ZIRCONYL PHOSPHATE LEUKEMIA AND LYMPHOMA	4	2	2	67	85
T	20	PD-103 SUSPENSION INTERSTITIAL THERAPY	2	2	0	8	8
T	28	I-131 MICROSPHERES INTERSTITIAL THERAPY	1	1	0	6	9
T	29	Y-90 MICROSPHERES INTERSTITIAL THERAPY	1	1	0	1	1
T	30	YB-169 MICROSPHERES INTERSTITIAL THERAPY	1	1	0	1	2
		TOTAL	7215	3138	4077	28664	33743

		BRACHYTHERAPY	LICENSED	USED	UNUSED	PATIENTS	ADMIN.
B	1	CO-60 NEEDLES OR WIRE INTERSTITIAL THERAPY	258	31	227	337	547
B	2	CO-60 NEEDLES OR SEEDS INTERSTITIAL THERAPY	283	90	193	1750	2737
B	3	SR-90 EYE APPLICATOR OPHTHALMIC TREATMENT	483	295	188	6552	11785
B	4	RN-222 SEEDS INTERSTITIAL THERAPY	436	158	278	2241	3069
B	5	RA-226 NEEDLES INTERSTITIAL THERAPY	604	276	328	3421	4152
B	6	RA-226 NEEDLES OR TUBES INTRACAVITARY THERAPY	734	543	191	10559	15700
B	7	RA-226 NASOPHARYNGEAL APPLICATOR INTRACAVITARY THERAPY	306	50	256	981	2457
B	8	RA-226 PLAQUES OR MOULDS DERMATOLOGICAL TREATMENT	378	109	269	2851	5582
B	10	RA-226 NASOPHARYNGEAL APPLICATOR NON-MALIGNANT CONDITIONS	18	12	6	138	383
B	11	IR-192 SEEDS OR RIBBON INTERSTITIAL THERAPY	51	32	19	401	404
B	12	SR-90 NASOPHARYNGEAL APPLICATOR NON-MALIGNANT CONDITIONS	6	6	0	466	678
B	13	RA-226 EYE APPLICATOR OPHTHALMIC TREATMENT	7	6	1	66	100
B	15	CS-137 NEEDLES OR TUBES INTRACAVITARY THERAPY	22	16	6	351	549
B	16	AU-198 SEEDS INTERSTITIAL THERAPY	20	12	8	96	106
B	22	CR-51 SEEDS INTERSTITIAL THERAPY	2	2	0	40	45
B	24	SR-90 NEEDLES NON-MALIGNANT CONDITIONS	1	1	0	1	1
B	26	RA-226 NEEDLES NON-MALIGNANT CONDITIONS	3	3	0	36	38
B	28	TA-182 WIRE INTERSTITIAL THERAPY	5	1	4	6	6
B	29	SR-90 PLAQUES DERMATOLOGICAL TREATMENT	8	7	1	664	1182
B	31	CO-60 PLAQUES DERMATOLOGICAL TREATMENT	2	2	0	3	5
B	35	CO-60 WIRE INTRAVASCULAR THERAPY	1	1	0	7	7
B	36	SR-90 NEEDLE HYPOPHYSEAL DESTRUCTION	1	1	0	30	30
B	39	CO-60 TUBES INTRACAVITARY THERAPY	1	1	0	4	8
B	40	Y-90 BEADS TRANSSPHENOIDAL HYPOPHYSECTORY	2	2	0	52	52
		TOTAL	3632	1657	1975	31053	49622

TELETHERAPY

			LICENSED	USED	UNUSED	PATIENTS	ADMIN.
C	1	CO-60 TELETHERAPY	524	399	125	153714	1859845
C	2	CS-137 TELETHERAPY	76	25	51	3364	60103
		TOTAL	600	424	176	157078	1919948

		THERAPEUTIC RESEARCH STUDIES	LICENSED	USED	UNUSED	PATIENTS	ADMIN.
R	1	CO-60 COMBINED WITH CHEMO-THERAPY	4	2	2	5	5
R	2	SR-90 EXTRACORPORAL IRRADIATION OF BLOOD FOR LEUKEMIA	1	1	0	1	1
R	3	P-32 POLYMETAPHOSPHATE BONE METASTASIS	3	1	2	2	2
R	4	C-14 TOPICAL APPLICATOR	1	1	0	1	30
R	5	Y-90 MICROSPHERES STEROTAXIC NEUROSURGERY	1	1	0	16	29
R	6	SR-90 EYE APPLICATOR VASCULARIZATION	1	1	0	10	10
R	7	S-35 SODIUM SULFATE TUMOR CONCENTRATION	1	1	0	1	1
R	8	RN-222 SEEDS TELEOTHALAMOTOMY	1	1	0	3	3
R	9	TH-228 THORIUM DIOXIDE BRAIN ABSCESS MARKING	1	1	0	4	8
R	10	SR-90 INTRATUBAL APPLICATOR EUSTACHIAN TUBE TREATMENT	1	1	0	6	6
R	12	P-32 OR SR-85 PHOTOSCANS BEFORE AND DURING THERAPY	1	1	0	20	45
R	13	I-131 LABELED ANTIBODIES THERAPY	1	1	0	3	3
R	14	AU-198 SEED IMPLANTS INTERSTITAL THERAPY	1	1	0	4	4
R	15	IR-192 RIBBONS INTERSTITAL THERAPY	1	1	0	2	2
R	16	P-32 PHOSPHATE SKIN MALIGANCY	1	1	0	5	10
R	17	P-32 PHOSPHATE OPHTHALMIC TREATMENT	1	1	0	1	5
R	18	Y-90 OXIDE OR CHLORIDE MALIGNANT EFFUSIONS	1	0	1	0	0
R	19	P-32 SODIUM PHOSPHATE TREATMENT OF THE PHARYNX	1	1	0	1	3
R	20	P-32 SODIUM PHOSPHATE MULTIPLE MYELOMA	1	1	0	1	6
R	21	P-32 CHROMIC PHOSPHATE JOINT EFFUSIONS	1	1	0	4	8
R	22	I-131 SODIUM IODIDE THYROID GOITER	1	0	1	0	0
		TOTAL	26	20	6	90	181

Appendix C

FOLLOWUP SURVEY RESULTS

Overall Survey Response

A total of 7,204 individuals is included in the directory of physicians identified as using radionuclides in medicine. Information has been received from 6,130 individuals for an overall response of 85 percent to the original and five followup surveys of the Phase I study.

Type of Nuclear Medicine Practice of Respondents

The physicians who responded to the original and the first four followup surveys were classified according to the primary type of nuclear medicine practice. This classification is shown in Table C-1.

Radionuclide Usage of Followup Survey Population

The second, third, and fourth followup surveys gave data on the fraction of radionuclide users in the population who had not responded to the original or first followup surveys. However, these surveys did not provide estimates of the numbers of patients or administrations. The purpose of the fifth followup survey was to select a sample of the active users reported in the third and fourth followup surveys and to obtain information on the numbers of patients and administrations by procedure. The response obtained from this survey is summarized in Table C-2.

The 47 percent response to this survey is similar to that obtained from the original and also the first followup survey. Since the third and fourth followup surveys had identified the entire population from which the sample was chosen for the fifth followup survey as active

Table C-1. Classification of survey respondents

Classification	Percent of Respondents to Survey				
	Original	First Followup	Second Followup	Third Followup	Fourth Followup
General nuclear medicine (function, scanning, therapy)	48.5	40.5	35.4	*	*
Diagnostic research	2.8	1.6	3.4	*	*
Therapy (brachytherapy, teletherapy, therapy research)	16.5	14.6	18.0	*	*
Subtotal of above	(67.8)	(56.7)	(56.8)	(33.8)	(66.8)
Physicians included in another response	11.6	8.6	10.7	36.9	0.0
Total users	79.4	65.3	67.5	70.7	66.8
Licensed nonusers	16.4	26.0	24.6	*	*
Nonpractitioners (includes retired and deceased)	4.1	8.3	7.9	*	*
Refused to answer	0.1	0.4	0.0	0.0	0.0
Total nonusers	20.6	34.7	32.5	29.2	33.2
Number of responding physicians in subgroup	2,876	980	178	1,042	1,056
Number of physicians surveyed	7,204	4,328	178	1,264	1,752

* Questionnaire did not obtain information in this detail.

Table C-2. Response for fifth followup survey

Type of Response	Respondents	
	Number	Percent of Total
Used radionuclides in 1966 (complete response)	71	74.7
Used radionuclides in 1966 (checked procedures used only)	3	3.2
Moved, records not available	2	2.1
Claims to have completed original 1966 survey	3	3.2
Does research procedures only	2	2.1
Refused to answer	1	1.1
Total users	(82)	(86.4)
Nonuser in 1966	13	13.6
Total	95*	100.0

* Questionnaires were sent to 202 physicians, therefore the response to the Fifth Followup Survey was 47 percent.

radionuclide users, the 13.6 percent of responders who indicated that they did not practice nuclear medicine in 1966 was not expected. This result was used to determine a reduction factor by which the number of users from the third and fourth followup survey was corrected to the number of active users in 1966.

The determination of the number of practitioners who used radionuclides in medicine in 1966 in the followup survey population, i.e., the population that did not respond to the original or first followup surveys, is shown in Table C-3. This determination uses a factor that reduces the number of users in the nonresponding population of the third and fourth followup surveys to 0.82 of that which is obtained by assuming the fraction of users for the nonresponders is the same as that for the responders.

This factor was obtained from the results of the original and first followup surveys and is the ratio of percent users of the first followup and the original surveys.

The number of practitioners of each procedure, the total number of patients and administrations for each procedure are shown in Table C-4 for the 71 complete responses obtained in the fifth followup survey. The usage characteristic results of this survey are compared with those of the original and first followup surveys in Table C-5 for each procedure.

Table C-3. Radionuclide users in nonresponding population

Category of Radionuclide Users	Number of Radionuclide Users in Category		
Second followup			101
Bad addresses of original and first followup			51
Estimate of National Institute of Health practitioners			43
Reported in third followup		352	
Reported in fourth followup		706	
Nonrespondents third followup[*]	75		
Nonrespondents fourth followup[*]	465		
Subtotal	540		
Corrected nonrespondents third and fourth followup[†]		443	
Users in third and fourth followup		1,501	
Adjusted users in third and fourth followup[‡]			1,296
Total users in nonresponding population			1,491

[*] Based on the fraction of users in the responding population.

[†] Based on a ratio of nonresponding to responding users = 0.82, which was determined from the Original and First Followup Surveys.

[‡] Based on a reduction factor for physicians reported as users but who did not actually practice nuclear medicine in 1966. This was taken to be 0.864 as a result of Fifth Followup Survey.

Table C-4. Total radionuclide procedure usage of the fifth followup survey respondents

Procedure*	Total Number		
	Practitioners	Patients	Administrations
Function			
F- 1	33	27,052	-
F-13	47	10,170	10,355
F- 9	23	3,216	3,281
F- 4	9	161	168
F- 5	16	124	125
F-12	15	953	973
F- 7	15	592	601
F- 8	15	657	683
F-11	17	267	282
F- 6	9	28	28
F-16	9	39	39
Scanning			
S- 8	35	4,927	4,987
S-54	0	0	0
S-1	6	1,409	1,417
S-18	24	2,504	2,562
S-22	11	1,136	1,140
S-26	2	9	9
S-15	23	1,341	1,352
S-11	18	559	560
S- 2	0	0	0
S- 9	18	336	342
S-17	24	352	352
S-13	6	317	323
S-12	2	4	4
S- 6	17	210	210
S- 7	1	7	7
S-10	9	82	83
S- 5	2	21	21
S- 4	9	44	44
S-14	2	10	10
S-20	11	57	57

* See Appendix B for procedure identification.

Table C-4 (continued)

Procedure	Total Number		
	Practitioners	Patients	Administrations
Therapy			
T- 4	40	593	609
T- 5	7	23	23
T- 6	10	30	32
T- 7	5	9	15
T- 1	18	86	91
T- 2	1	1	1
T- 3	10	23	23
T- 8	4	10	10
Brachytherapy			
B- 6	19	1,414	2,448
B- 5	4	12	12
B- 8	2	22	22
B-10	2	8	26
B- 4	5	13	13
B- 3	7	250	551
B- 2	4	247	247
B- 1	2	46	48
Teletherapy			
C- 1	14	16,062*	55,348
C- 2	2	1,036	12,912

* With this many patients, the number of administrations reported corresponds to 3.44 administrations per patient. This is not consistent with 12.2 administrations per patient obtained with the original and first followup surveys. Nor is it consistent with treatment plans of 3 to 4 weeks between exposures. Using 12.2 administrations per patient and the reported number of administrations the resultant number of patients is 4,537.

Table C-5. Comparison of response by procedure from original, and first and fifth followup surveys

Procedure*	Percent of all Physicians Using Procedure			Patients per Physician Using Procedure			Administrations per Patient		
	Original	First	Fifth	Original	First	Fifth	Original	First	Fifth
Function									
F- 1	36	36	46	532	600	820			
F-13	44	42	66	229	227	216	1.1	1.0	1.0
F- 9	32	29	32	97	120	140	1.1	1.1	1.0
F- 4	15	14	13	50	33	18	1.1	1.1	1.0
F- 5	21	20	22	11	9	8	1.1	1.0	1.0
F-12	14	12	21	83	57	64	1.1	1.1	1.0
F- 7	20	19	21	41	35	39	1.1	1.1	1.0
F- 8	19	18	21	29	23	44	1.1	1.1	1.0
F-11	18	16	24	12	14	16	1.2	1.0	1.1
F- 6	10	9	13	9	16	3	1.0	1.1	1.0
F-16	1	1	13	29	3	4	2.1	1.0	1.0
Scanning									
S- 8	31	30	49	160	138	141	1.1	1.0	1.0
S-54	<1	0	0	338	-	-	1.0	-	-
S- 1	11	13	8	185	190	235	1.0	1.0	1.0
S-18	11	10	34	116	113	104	1.0	1.0	1.0
S-22	5	4	15	133	78	103	1.1	1.0	1.0
S-26	1	1	3	78	163	5	1.1	1.0	1.0
S-15	18	18	32	78	67	58	1.0	1.0	1.0
S-11	17	17	25	40	35	31	1.0	1.0	1.0
S- 2	2	2	0	93	80	-	1.0	1.0	-
S- 9	19	21	25	41	30	19	1.1	1.0	1.0
S-17	19	18	34	30	29	15	1.0	1.0	1.0
S-13	9	10	9	26	18	53	1.0	1.0	1.0
S-12	3	4	3	23	14	2	1.0	1.0	1.0
S- 6	14	14	24	14	19	12	1.0	1.0	1.0
S- 7	1	1	1.4	17	26	7	1.0	1.0	1.0

* See Appendix B for Procedure descriptions.

Table C-5 (continued)

Procedure	Percent of all Physicians Using Procedure			Patients per Physician Using Procedure			Administrations per Patient		
	Original	First	Fifth	Original	First	Fifth	Original	First	Fifth
Scanning (continued)									
S-10	11	12	13	12	9	9	1.0	1.0	1.0
S- 5	4	3	3	14	9	11	1.0	1.0	1.0
S- 4	10	9	13	6	5	5	1.0	1.0	1.0
S-14	2	2	3	8	4	5	1.0	1.0	1.0
S-20	2	2	15	9	5	5	1.0	1.0	1.0
Therapy									
T- 4	36	34	56	18	15	15	1.1	1.1	1.0
T- 5	10	9	10	7	4	3	1.2	1.2	1.0
T- 6	11	11	14	5	4	3	1.2	1.2	1.1
T- 7	25	6	7	4	2	2	1.2	1.1	1.1
T- 1	19	21	25	5	4	5	1.4	1.1	1.1
T- 2	5	5	1	4	4	1	1.7	1.7	1.0
T- 3	10	13	14	12	5	2	1.1	1.1	1.0
T- 8	5	5	6	4	5	3	1.1	1.0	1.0
Brachytherapy									
B- 6	18	20	27	20	18	74	1.6	1.2	1.7
B- 5	9	9	6	12	14	3	1.3	1.1	1.0
B- 8	3	5	3	29	20	11	1.9	2.2	1.0
B-10	<1	<1	3	12	7	4	2.7	3.7	3.3
B- 4	4	9	7	17	7	3	1.4	1.3	1.0
B- 3	10	9	10	21	27	36	1.9	1.5	2.2
B- 2	3	4	6	19	20	62	1.7	1.1	1.0
B- 1	1	1	3	11	12	23	1.8	1.0	1.0
Teletherapy									
C- 1	13	14	21	433	230	1,147	11.0	18.6	3.5*
C- 2	1	<1	3	140	69	518	17.8	20.0	12.5

* See footnote of Table C-4.

APPENDIXES

PHASE II

Appendix D

SURVEY QUESTIONNAIRES AND COVERING LETTER

Two survey questionnaires were developed for this study of 23 diagnostic radiopharmaceutical procedures. One (Exhibit D-1) applies to all scanning and the thyroid function procedures, and differs from the other (Exhibit D-2), which applies to the remaining function procedures, in that the former contains a question on radiopharmaceutical modification that is omitted in the latter.

STANFORD RESEARCH INSTITUTE

MENLO PARK, CALIFORNIA 94025

March 5, 1969

John D. White, M.D.
Hendrick Memorial Hospital
1350 East Middlefield Street
Menlo Park, California 94025

Dear Dr. White:

You will recall from having completed the initial questionnaire of this study over a year ago, that Stanford Research Institute has been requested by the United States Public Health Service to obtain information on the use of radionuclides in medicine. The enclosed table summarizes results from the initial survey, and the Public Health Service is forwarding to you a report from that investigation, "Survey of the Use of Radionuclides in Medicine: Preliminary Report."

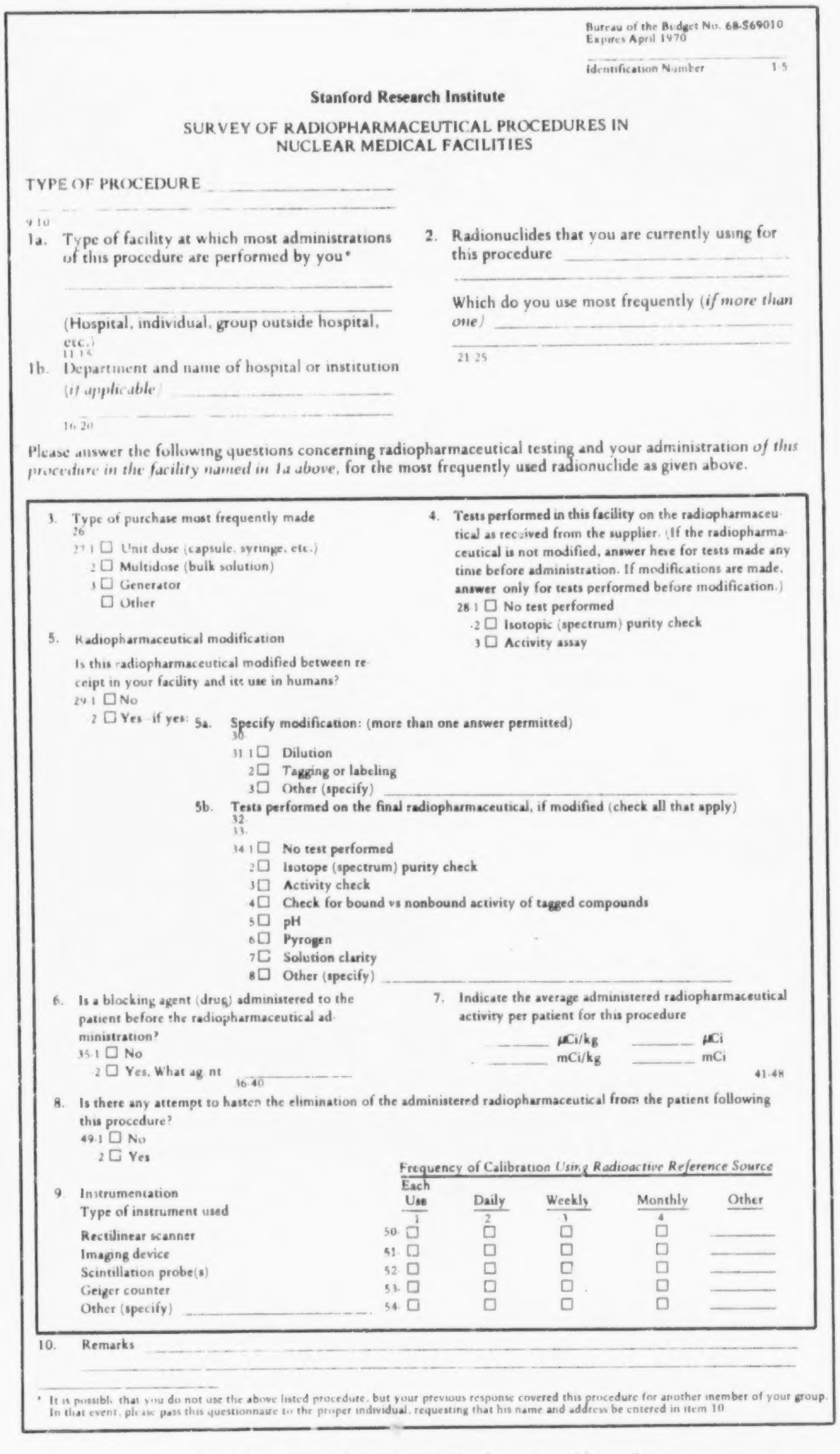
The second phase of the survey includes a qualitative study of radiopharmaceutical testing and manipulation, patient preparation, and instrumentation. A selected sample of responders from the first phase are being asked to supply information on 23 procedures representing over 95 percent of the reported radiopharmaceutical administrations. The results will afford a documentation of the current state of the art of nuclear medicine. We would like you to complete the enclosed questionnaire concerning just one specific procedure as currently utilized by you.

Your assistance will once again be greatly appreciated and your prompt attention is earnestly requested. All answers will be kept confidential and only aggregated data will be reported.

Yours sincerely,
for Stanford Research Institute

William J. Rees, M.D.

wjr:tr
encl.



Bureau of the Budget No. 68-S69010
Expires April 1970

Identification Number 1-5

Stanford Research Institute

SURVEY OF RADIOPHARMACEUTICAL PROCEDURES IN
NUCLEAR MEDICAL FACILITIES

TYPE OF PROCEDURE ____________________
9 10

1a. Type of facility at which most administrations of this procedure are performed by you* ____________________
(Hospital, individual, group outside hospital, etc.)
11 15

1b. Department and name of hospital or institution (*if applicable*) ____________________
16 20

2. Radionuclides that you are currently using for this procedure ____________________

Which do you use most frequently (*if more than one*) ____________________
21 25

Please answer the following questions concerning radiopharmaceutical testing and your administration *of this procedure in the facility named in 1a above*, for the most frequently used radionuclide as given above.

3. Type of purchase most frequently made
26
27 1 ☐ Unit dose (capsule, syringe, etc.)
2 ☐ Multidose (bulk solution)
3 ☐ Generator
☐ Other

4. **Tests performed in this facility** on the radiopharmaceutical as received from the supplier. (If the radiopharmaceutical is not modified, answer here for tests made any time before administration. If modifications are made, answer only for tests performed before modification.)
28 1 ☐ No test performed
-2 ☐ Isotopic (spectrum) purity check
3 ☐ Activity assay

5. Radiopharmaceutical modification

Is this radiopharmaceutical modified between receipt in your facility and its use in humans?
29 1 ☐ No
2 ☐ Yes - if yes:

5a. Specify modification: (more than one answer permitted)
30
31 1 ☐ Dilution
2 ☐ Tagging or labeling
3 ☐ Other (specify) ____________________

5b. Tests performed on the final radiopharmaceutical, if modified (check all that apply)
32
33
34 1 ☐ No test performed
2 ☐ Isotope (spectrum) purity check
3 ☐ Activity check
4 ☐ Check for bound vs nonbound activity of tagged compounds
5 ☐ pH
6 ☐ Pyrogen
7 ☐ Solution clarity
8 ☐ Other (specify) ____________________

6. Is a blocking agent (drug) administered to the patient before the radiopharmaceutical administration?
35-1 ☐ No
-2 ☐ Yes, What ag nt ____________
36-40

7. Indicate the average administered radiopharmaceutical activity per patient for this procedure
_______ μCi/kg _______ μCi
_______ mCi/kg _______ mCi
41-48

8. Is there any attempt to hasten the elimination of the administered radiopharmaceutical from the patient following this procedure?
49-1 ☐ No
-2 ☐ Yes

9. Instrumentation

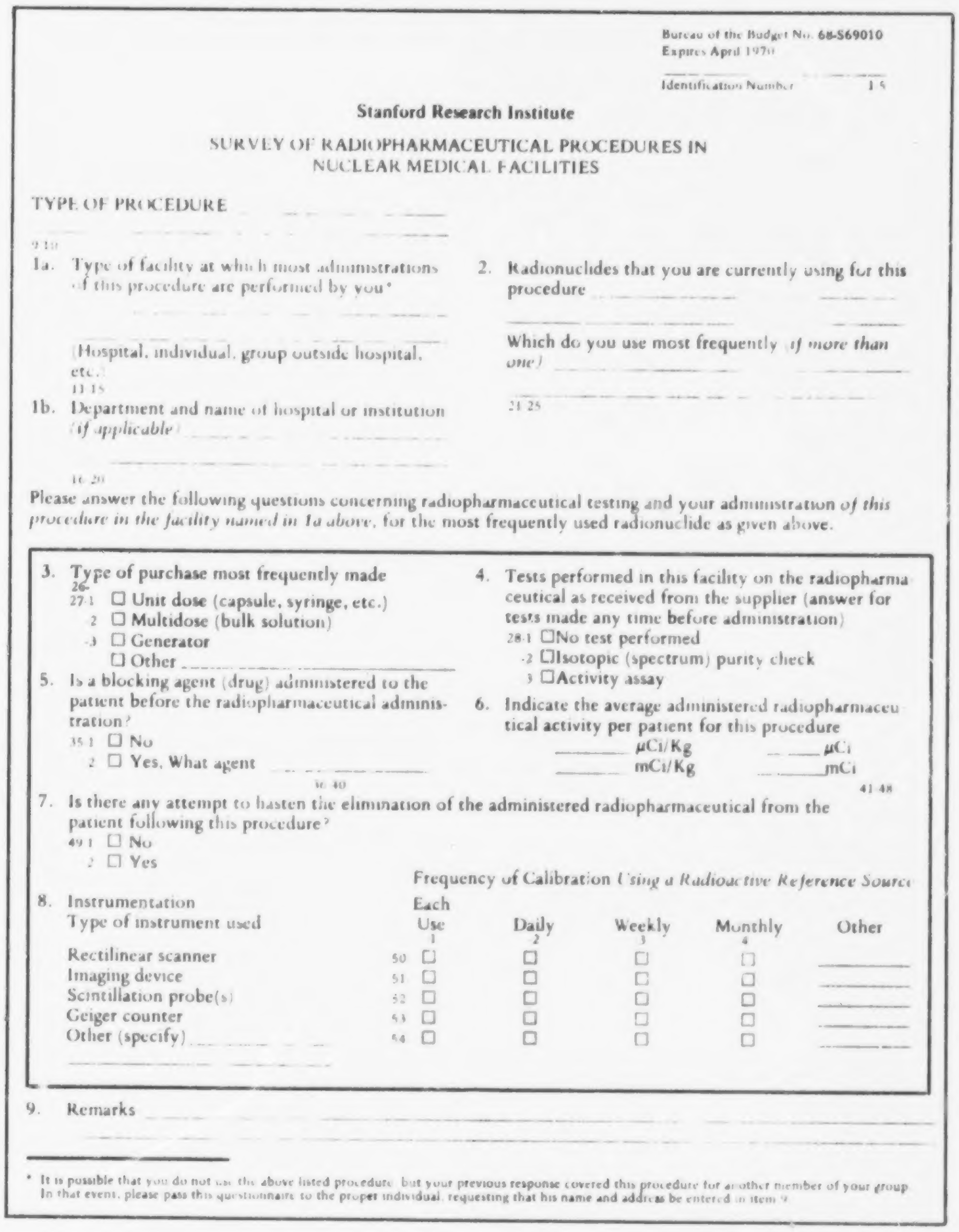
Type of instrument used		Frequency of Calibration *Using Radioactive Reference Source*				
		Each Use 1	Daily 2	Weekly 3	Monthly 4	Other
Rectilinear scanner	50-	☐	☐	☐	☐	________
Imaging device	51-	☐	☐	☐	☐	________
Scintillation probe(s)	52-	☐	☐	☐	☐	________
Geiger counter	53-	☐	☐	☐	☐	________
Other (specify) ____________	54-	☐	☐	☐	☐	________

10. Remarks ____________________

---

* It is possible that you do not use the above listed procedure, but your previous response covered this procedure for another member of your group. In that event, please pass this questionnaire to the proper individual, requesting that his name and address be entered in item 10.

Exhibit D-1. Scanning procedure questionnaire



Bureau of the Budget No. 68-S69010
Expires April 1970

Identification Number ______ 1-5

Stanford Research Institute

SURVEY OF RADIOPHARMACEUTICAL PROCEDURES IN
NUCLEAR MEDICAL FACILITIES

TYPE OF PROCEDURE ____________________
9-10

1a. Type of facility at which most administrations of this procedure are performed by you* ____________________
(Hospital, individual, group outside hospital, etc.)
11-15

1b. Department and name of hospital or institution (*if applicable*) ____________________
16-20

2. Radionuclides that you are currently using for this procedure ____________________

Which do you use most frequently (*if more than one*) ____________________
21-25

Please answer the following questions concerning radiopharmaceutical testing and your administration *of this procedure in the facility named in 1a above*, for the most frequently used radionuclide as given above.

3. Type of purchase most frequently made
26-
27-1 ☐ Unit dose (capsule, syringe, etc.)
-2 ☐ Multidose (bulk solution)
-3 ☐ Generator
☐ Other ____________________

4. Tests performed in this facility on the radiopharmaceutical as received from the supplier (answer for tests made any time before administration)
28-1 ☐No test performed
-2 ☐Isotopic (spectrum) purity check
3 ☐Activity assay

5. Is a blocking agent (drug) administered to the patient before the radiopharmaceutical administration?
35-1 ☐ No
2 ☐ Yes, What agent ____________
36-40

6. Indicate the average administered radiopharmaceutical activity per patient for this procedure
______ μCi/Kg ______ μCi
______ mCi/Kg ______ mCi
41-48

7. Is there any attempt to hasten the elimination of the administered radiopharmaceutical from the patient following this procedure?
49-1 ☐ No
2 ☐ Yes

8. Instrumentation

Type of instrument used		Frequency of Calibration *Using a Radioactive Reference Source* Each Use 1	Daily 2	Weekly 3	Monthly 4	Other
Rectilinear scanner	50	☐	☐	☐	☐	______
Imaging device	51	☐	☐	☐	☐	______
Scintillation probe(s)	52	☐	☐	☐	☐	______
Geiger counter	53	☐	☐	☐	☐	______
Other (specify) ______	54	☐	☐	☐	☐	______

9. Remarks ____________________

---

* It is possible that you do not use the above listed procedure but your previous response covered this procedure for another member of your group. In that event, please pass this questionnaire to the proper individual, requesting that his name and address be entered in item 9.

Exhibit D-2. Function procedure questionnaire

Appendix E

PRETEST PROGRAM

Objective

A pretest program was conducted that was designed to confirm the adequacy of the questionnaire characteristics and the physician sampling criteria in terms of promptness, completeness, and accuracy of response. The pretest sample was selected to investigate response characteristics for the following variables: (1) the function and the scanning questionnaires, (2) the number of questionnaires sent to a respondent, and (3) physicians who answer for private practice and those who answer for group or hospital practices. In addition it was desired to sample as many of the 23 diagnostic radiopharmaceutical procedures as possible, as well as to sample physicians who responded to both of the Phase I questionnaire mailings.

Approach

Pretest Sample

The pretest sample was selected to reflect the sources of variability mentioned above. A sample of 20 physicians was selected from the list of those not appearing in the major Phase II sample. Nine physicians came from private practice addresses and 11 represented hospital addresses. Fifteen of these physicians were respondents to the first mailing of Phase I and 5 were respondents to the second mailing. The 20 physicians were to be sent 41 questionnaires on 19 procedures. The four procedures with no questionnaires for the pretest are those that were sampled 100 percent in the major Phase II mailing.

Pretest Mailing

The pretest questionnaires were airmailed on December 3, 1968. Each physician received the cover letter, the appropriate number of questionnaires with the name of the procedure filled in, and a pre-addressed and stamped, return airmail envelope.

Results

The principal results from the Phase II pretest are summarized below.

Questionnaire Design

The only substantial problem regarding the questionnaires was that having to do with the question on frequency of calibration. Several of the respondents deviated from the expected reply to this question. This may be due in part to a general reticence to answer this question. On the other hand, it is not always an easily answered question. For example, one physician stated that several components of a given piece of equipment are calibrated at different time intervals.

Errors that were made in completing the pretest questionnaire are estimated to be in the normal range of human error for busy physicians, and no requirement is seen for major changes in the questionnaires.

Discussions with respondents indicated that in designing two questionnaires to cover 23 procedures, some compromises must be made that will lead to minor complications; however, they also indicated that these complications were of a minor nature.

Response Patterns

Ample evidence was offered that physicians are a very busy group. One stated that he had no intention of completing the questionnaires, and two others would probably not have completed them without a telephone followup. The telephone followup indicated that at least two physicians made mistakes in their questionnaires due wholly to the haste with which they were completed. The overall response seemed to be somewhat slow. This may be a further indication of the physicians' heavy work load. Another factor affecting this could be the mailing shortly before the Christmas holiday period.

A greater percentage of the prompt Phase I respondents (93%) responded to the Phase II pretest than did the later Phase I respondents (60%). There does not, however, appear to be a correlation between the response and the number of questionnaires received by the respondent.

The results suggest that physicians having a hospital address are more likely to respond than those having a non-hospital address (100% versus 57%).

A higher percentage of the function procedure questionnaires were returned than of the scanning procedure questionnaires (93% versus 78%). The scanning questionnaire contains one more question than the function questionnaires.

Appendix F

RADIOPHARMACEUTICAL PROCEDURES

The diagnostic radiopharmaceutical procedures considered in this study are briefly described in this appendix. This description is based on the recent editions of two comprehensive works in the field of nuclear medicine.[*] These descriptions are included to give the reader who is unfamiliar with the practice of nuclear medicine, or perhaps with some of the procedures covered by the Phase II surveys, some understanding of how the procedures are generally performed and how the unique properties of the radiopharmaceutical are used.

The reader is directed to another recent publication for descriptions of the procedures in sufficient detail to provide clinical guidance.[†] The administered activities for each of these procedures as reported by the authors are given in Table F-1, together with the whole body and critical organ radiation doses reported by Maynard.

Vitamin B-12 Malabsorption--Cobalt 57 or Cobalt 60 Cyanocobalmine (F-7, F-8)

One important function of vitamin B-12 is an effect on the rate of synthesis of deoxyribonucleic acid (DNA) and cell division. Although many organ systems are affected by deficiency of this important coenzyme, the common clinical manifestations of deficiency are megaloblastic

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[*] Silver, Solomon, M.D., Radioactive Nuclides in Medicine and Biology Third Edition, Philadelphia, Lea & Febiger, 1968.
Wagner, Henry J. Jr., M.D., ed., Principles of Nuclear Medicine, Philadelphia, W. D. Saunders Company, 1968.

[†] Maynard, C. Douglas, M.D., Clinical Nuclear Medicine, Philadelphia, Lea & Febiger, 1969.

Table F-1. Reported administered activities and radiation doses for selected radiopharmaceutical procedures

Procedure	Administered Activity, Microcuries			Radiation Dose According to Maynard	
	Silver	Wagner	Maynard	Whole Body, mrads	Critical Organ, rads
P-32 Blood Volume (F-3)	2-3	--	--	--	--
Cr-51 Blood Volume (F-4	5	10	30-50*	--	--
I-125/131 Blood Volume (F-9)	3-20	10	5	30-100	--
Co-57 Vitamin B-12 (F-7)	0.5	1	0.5	5-6	0.1-0.2 (liver)
Co-60 Vitamin B-12 (F-8)	0.5	1	0.5	200-300	4-5 (liver)
I-125/131 Fat Absorption (F-11)	1-50	25-50	25-50	--	--
I-125/131 Kidney Function (F-12)	10-30	20-40	15-20 I-131	0.6	0.02 (kidney)
			20-30 I-125	0.2	0.004 (kidney)
I-131 Thyroid Function (F-13)	1-25	50	5-10	2-5	5-15 (thyroid)
I-131 Thyroid Scan (S-8)	50-100	15-25	50-100	20-50	50-150 (thyroid)
Tc-99m Brain Scan (S-1)	$(5-15)10^3$	15×10^3	$(10-15)10^3$	200	2.0 (colon)
Hg-203 Brain Scan (S-18)	700	750	700	400	165 (kidney)
Hg-197 Brain Scan (S-22)	700	750	1,000	90	13 (kidney)
Tc-99m Liver Scan (S-2)	$(1-3)10^3$	2,000	$(1-2)10^3$	8-20	0.3-0.6 (liver)
I-131 Liver Scan (S-11)	300	150	150	220	0.2-0.7 (liver)
Au-198 Liver Scan (S-15)	300	150	150	100-240	4-7 (liver)
Sr-85 Bone Scan (S-6)	50	100-200	75-100	1,600	3.1 (bone)
Sr-87m Bone Scan (S-7)	10-1,500	2,000	$(1-3)10^3$	2	0.03 (bone)
I-131 Lung Scan (S-9)	100-300	300	200-300	--	3.4 (lung)
I-125/131 Placenta Scan (S-10)	1-5	--	5-10	10 (mother)	0.073 (mother)(blood)
				4 (fetus)	0.005 (fetus)(blood)
Cr-51 Placenta Scan (S-25)	10	--	30-50	40 (mother)	0.004 (mother)(blood)
				25 (fetus)	0.005 (fetus)(blood)
I-131 Kidney Scan (S-12)	--	--	200	6	0.2 (kidney)
Hg-197 Kidney Scan (S-13)	150	300	75-100	10	1-2 (kidney)
Hg-203 Kidney Scan (S-17)	150	150	75-100	20	15-20 (kidney)

* Activity used to label red blood cells.

and macrocytic anemia and neurological abnormalities resulting from subacute combined degeneration of the spinal cord.

The vitamin B-12 molecule consists of two basic units, a planar group and a nucleotide chain. The planar group has four pyrrole rings joined to a central atom of cobalt. Vitamin B-12 is synthesized by microorganisms growing in soil, in water, and in the intestines or rumens of certain animals. If radioactive cobalt is added to the growth media of appropriate bacteria, the radioactive label is incorporated into the vitamin.

After ingestion, vitamin B-12 combines with gastric intrinsic factor and passes to the terminal ileum, where absorption takes place. Intrinsic factor is a very stable protein that is relatively resistant to acid, alkali, and the proteolytic enzymes in the gastrointestinal tract. The small amount of vitamin B-12 not absorbed (20 to 30 percent) is excreted in the feces. The vitamin B-12-intrinsic factor complex is absorbed through the intestinal wall and free vitamin B-12 is released in the portal venous blood. Once in the blood, vitamin B-12 forms a firm bond with a specific binding globulin in plasma. Most is transported to the liver; smaller amounts are delivered to other tissues. The firm bond between vitamin B-12 and the plasma proteins prevents renal excretion of the vitamin.

A lack of intrinsic factor is the mechanism of malabsorption of vitamin B-12 in Addisonian pernicious anemia and following total gastrectomy. Abnormalities within the small intestine can also cause malabsorption of vitamin B-12. A third mechanism of vitamin B-12 deficiency is disease of the intestinal wall at the absorption site in the terminal ileum.

Vitamin B-12 oral absorption studies are of great value in the diagnosis of pernicious anemia, postgastrectomy anemias, and the separation of the nutritional macrocytic anemias from true Addisonian anemia.

Four methods have been applied clinically to study vitamin B-12 absorption. In each, about 0.5 μg of the vitamin labeled with from 0.5 to 1.0 μCi of radioactive cobalt is given by mouth after a 12-hour fast.

1. Fecal Excretion. All stools are collected for at least 72 hours or until a single specimen contains less than 1 percent of the administered dose. Normally, not more than 50 percent appears in the stool. In pernicious anemia from 85 to 100 percent is recovered and normal values are obtained when the test is repeated with intrinsic factor.

2. Hepatic Uptake. This test is based on the fact that absorbed vitamin B-12 is fixed in the liver and retained there for many months, or even years. The rate of accumulation of radioactivity in the liver is measured with an external radiation detector.

3. Urine Collection. To promote renal excretion of absorbed vitamin B-12 a large dosage of stable vitamin, usually 1,000 μg, is given subcutaneously as a "flushing dose" or "saturation dose" within two hours after the oral test dosage. The stable vitamin B-12 saturates the tissue and plasma vitamin B-12 binding sites before the absorption of most of the radioactive vitamin B-12. A portion of the radioactive vitamin subsequently absorbed remains unbound and is excreted by the kidney. With this test, absorption is considered normal if more than 15 percent is recovered in the 24-hour urine. Values of less than 7 percent excretion indicate significant malabsorption of vitamin B-12.

4. Blood Plasma Levels. Plasma radioactivity increases from about four hours after administration of the test dose until a peak value is reached between 8 and 14 hours. Patients having a value lower than 0.18 percent of the dosage per 1 percent body weight are considered to have malabsorption of vitamin B-12. Two isotopes of cobalt, ^{60}Co and ^{57}Co, are commonly used labels of vitamin B-12. Cobalt 60 has a longer physical half-life and decays by beta emission. Therefore, the radiation to the liver is greater than with ^{57}Co. Cobalt 57 can be obtained with a much greater specific activity. Because of its low gamma-photon energy, it can be counted more efficiently with sodium iodide detectors. Only with ^{57}Co is it practical to measure the small amounts of radioactivity in plasma following oral dosages of the radioactive vitamin.

Blood Volume Determination

Phosphorus 32 Sodium Phosphate (F-3)

Red cells can be conveniently labeled with ^{32}P in vitro. Ten mℓ of freshly drawn heparinized blood from the subject are incubated at 37°C with 0.1 or 0.2 mℓ of a solution containing about 10 μCi ^{32}P in the form of Na_2HPO_4 for about one hour. About 2 to 3 μCi of ^{32}P will have become fixed to the red cells. This is a fairly stable binding but will break down at the rate of about 6 percent per hour. The blood is cooled and the red cells separated by centrifuging. They are washed several times with cold saline solution to remove adherent plasma completely. The tagged cells are then resuspended in the original plasma or saline solution and a known volume of the suspension is reinjected intravenously. The activity of the injected suspension is determined by a suitable counting technique. After a period of time adequate for mixing (10 minutes) a sample of the patient's blood is drawn and its activity determined. The circulating red cell volume is determined from the activity dilution.

Chromium 51 Sodium Chromate (F-4)

The principles of red cell mass determination by the use of in vitro tagging with ^{51}Cr are the same as those with ^{32}P. The patient's own blood or group O-Rh-negative blood can be used. For each 10 mℓ of heparinized blood or blood preserved with the standard acid-citrate-dextrose mixture, about 50 μCi of radiochromate is added and the mixture incubated for one hour at 37°C with gentle shaking at frequent intervals. At the end of this time, 30 mg of ascorbic acid is added to reduce the chromate and stop the red cell tagging. The red cells can be washed and resuspended in the plasma or the entire blood can be used, since the ^{51}Cr present in the supernatant plasma can be determined and correction for this can be made. A known volume of the tagged mixture containing about 15 μCi ^{51}Cr is then injected into the patient and samples of venous blood are drawn at a suitable time (20 minutes to several hours). The circulating red cell volume is determined from the activity dilution using specific activities determined for the tagged red cells or whole blood, the diluted specimen from the patient, and the tagged and diluted plasma. Hematocrits of tagged whole blood and mixed patients' blood are also required.

Iodine 125 or Iodine 131 Albumin (F-9)

The determination of the circulating plasma volume can easily be made by the isotope dilution technique employing serum albumin labeled with ^{125}I or ^{131}I. Iodine 125 is more commonly used because of its longer shelf life and because it is less likely to liberate free iodide. It also allows simultaneous estimation of red cell mass using ^{51}Cr since their activities may be determined from the same sample by the gamma ray spectrometer.

The iodated human serum albumin is injected intravenously and a sample of the patient's blood is withdrawn after a suitable time to allow complete mixing. Because there is some "leakage" from the circulation, it is best to draw several samples during the first hour after injection and extrapolate back to zero time to get the concentration of the tagged compound when complete mixing first occurs.

In all procedures using ^{131}I iodated human serum albumin it is advisable to block thyroidal uptake of any liberated iodide by premedication with stable iodine and this medication is then continued for several days.

Fat Malabsorption Iodine 125 or Iodine 131 Labeled Fats and Fatty Acids (F-11)

Dietary lipids include triglycerides, phospholipids, sterols, terpene derivatives, and a variety of alcohol and aldehyde derivatives of fatty acids. Malabsorption of lipids can result from impaired digestive function, from deranged intestinal motility, from excessive secretion, or from an inadequate absorptive surface as the result of inflammation or surgical ablation. Absorption may be impaired by alterations in the fine structure of the intestine, or from failure of biochemical reactions essential for normal function.

A time-honored test for malabsorption of fat is the gross and microscopic examination of a fecal specimen. The availability of fat labeled with radioactive iodine has allowed the refinement of this procedure. As presently used, the procedure can distinguish whether an abnormality is due primarily to lack of proper digestive enzymes or to an intrinsic disorder in the absorption process. If there is a lack of digestive enzymes, a triglyceride (such as triolein) that cannot be digested will not be absorbed, but a fatty acid (such as oleic acid) will be absorbed without difficulty.

Dosages of about 0.5 gram of the labeled fat containing about 25 μCi of ^{131}I or ^{125}I are used followed by a dosage of carrier fat containing 1 gram per kilogram of body weight. The total amount of the administered substance that can be recovered in the stool within 72 hours after oral feeding is measured, and the difference between this value and the administered dose is considered as the absorbed fraction. Normal subjects pass only minimal amounts of the tagged neutral fat in the stool in the first 72 hours after feeding. In various diseases of the digestive tract that interfere with absorption, much larger amounts of the tagged fat can be recovered in the stool.

Blood plasma levels of radioactivity reach a peak in 4 to 6 hours after oral tracer dosages of fats. The normal range of peak blood levels is 1.4 to 4 percent of the administered dosage per liter of whole blood. If gastric emptying is delayed, the 4 to 6 hour blood levels may be low. This may be evaluated by administering 3 ounces of thin barium following the fat dosage and obtaining a radiograph of the stomach at 6 hours. The Blood Level and Fecal Excretion tests may be accomplished together using the same fat dose.

If radioactive-iodine-labeled oleic acid is used, the test is performed in exactly the same manner as with labeled triolein. In pancreatic insufficiency, the absorption of the oleic acid would be expected to be normal. In malabsorption syndrome due to small-bowel disease, absorption of both oleic acid and triolein will be poor.

Stable iodine is usually administered to block thyroidal uptake of any liberated iodide ^{131}I.

Kidney Function Iodine 125 or Iodine 131 Sodium Orthoiodohippurate (F-12)

The most frequent use of radioisotopes in renal disease has been in screening hypertensive patients to find those who may have surgically correctable unilateral renal disease. To detect unilateral renal disease, external radiation detectors are positioned at the surface of the body and directed toward each kidney. A gamma-emitting radiopharmaceutical is administered intravenously, and the rate of accumulation and disappearance of the radioactivity over the two kidneys is recorded. An abnormal result indicates only that there are functional or structural differences between the two kidneys.

In obtaining a renogram it is essential to have the detectors correctly positioned over the kidneys. The detector systems should be balanced before the test.

The detectors are usually connected to dual rate meters and rectilinear chart recorders. A dosage of 100 μCi of Hippuran is given intravenously, and a 15 to 20 minute tracing is made at a paper speed of 12 inches per minute. The radioactivity over the kidneys reaches a maximum in 5 minutes, followed by an approximately exponential decline during the next 10 to 15 minutes. Each laboratory should determine the range of normality with its own equipment on a series of normal patients, rather than relying only on some "ideal normal" curve.

Thyroid Function Iodine 131 Sodium Iodide Thyroid Uptake and Excretion (F-13)

Iodine 131 is useful in thyroid diagnosis and therapy because of the role that iodine plays in thyroid function. Radioactive isotopes of iodine, such as ^{131}I, follow the exact metabolic pathways of the normally occurring stable iodine. Because of this, it can be used as a tracer and the various fates of stable iodine can be accurately and easily measured with appropriate radioactivity detection equipment.

A widely used test of thyroid function is direct measurement of the rate of accumulation of ^{131}I by the thyroid gland by means of an external radiation detector. A dosage of ^{131}I is administered orally or intravenously. After standardized intervals, such as 1, 2, 6, or 24 hours, radioactivity in the thyroid is measured under standardized conditions and is compared with the amount present in a reference source containing a known quantity of ^{131}I. Since the absolute quantity of iodide in the extra-thyroidal pool is usually not known, one cannot determine the absolute value of iodide accumulatinn in mass per unit time. The result measures the fraction of the extra thyroidal iodide pool that is being accumulated per unit time. The procedure is valid, since an overactive thyroid gland turns over the plasma iodide pool faster than a normally active gland, and an underactive gland turns over iodide more slowly, provided the body's iodide stores are in the usual range.

Circulating iodide is ultimately disposed of by two competing mechanisms. These are thyroidal uptake and urinary excretion. It is apparent that urinary excretion, in general, bears a reciprocal relationship to thyroidal uptake and can be used as an indirect measure of thyroid function. Determination of the 24 or 48-hour excretion of radioiodine into the urine is a simple test. Urinary excretions of less than the tracer dose in 24 hours are consistent with the diagnosis of hyperthyroidism. Excretions in excess of 40 percent are usually associated with normal or decreased thyroid function.

Thyroid Scanning Iodine 131 Sodium Iodide (S-8)

Thyroid scanning is an example of the use of a physiological mechanism to concentrate a radionuclide and make possible the visualization of the structure of an organ. The method usually is combined with measurement of the rate of accumulation of the tracer by the thyroid, thereby providing functional as well as anatomical information.

Among the principal uses of thyroid scanning are the identification of accessory thyroid tissue, which may be found anywhere in the midline from the mouth to the diaphragm, and the localization of functioning metastatic neoplasms originating in the thyroid gland.

With equipment presently available, scanning studies can be carried out after a tracter dosage that allows 10 to 30 μCi of ^{131}I to be accumulated by the thyroid gland of normal size at the time the scan is performed, usually 24 hours. Two techniques have been used. In "hand scanning" the collimated detector is placed over the selected sites by visual or tactile control and the counting rates are read from a ratemeter or a scaling circuit. In "automatic scanning" the detector is moved mechanically in one or more planes and the counting rate is automatically recorded at selected times and spacings.

Lung Scanning Iodine 131 Albumin Macroaggregates (S-9)

Regional pulmonary arterial blood flow can be measured by the particle distribution method. Macroaggregates of human serum albumin (MAA) labeled with ^{131}I have been the most widely used radioactive particles for this purpose. The particle distribution method is based on the assumptions that: (1) the particles are uniformly mixed in the blood; (2) hemodynamic and gravitational forces affect the particles in a manner similar to that of red blood cells; (3) the particles are nearly completely extracted from the pulmonary circulation in a single passage through the lung; (4) the particles do not themselves alter the distribution of blood flow; (5) the particles are not metabolized so rapidly that the initial distribution is significantly altered before their detection; and (6) proper calibration can be made for the various shielding and geometric effects. Studies with the method have resulted in no evidence to discard any of these assumptions.

Ten drops of Lugol's solution in an ounce of water is given on the day before the scan, to block uptake of ^{131}I iodide by the thyroid. Administration of Lugol's solution is continued for three subsequent days.

Three hundred µCi of ^{131}I MAA is injected intravenously. The scan is begun immediately thereafter. The dosage of MAA should not exceed 0.1 milligram protein per kilogram body weight. The injection is given over a period of from 6 to 10 seconds to average out differences in respiratory cycles.

Placenta Scanning

Accurate placental localization is important in differentiating placenta previa from other causes of bleeding in the third trimester of pregnancy. As with any highly vascularized organ the placental blood pool can be delineated by radionuclide tagging of the patient's blood.

Iodine 125 or Iodine 131 Albumin (S-10)

Human serum albumin tagged with ^{131}I is injected intravenously in dosages of 2 to 5 µCi and counts can be made over the uterus beginning about 10 minutes later and can be repeated if necessary for several hours. There is only minimal transfer of the colloid across the placental barrier to the fetal circulation. The mother is pretreated with Lugol's solution, which greatly decreases the fetal and maternal thyroid irradiation. Absorbed radiation can be further reduced by using ^{125}I tagged material that emits no beta particle. However, the poor penetration of the gamma ray may cause decreased sensitivity in scanning.

Chromium 51 Sodium Chromate (S-25)

Chromium 51 tagged red blood cells do not for all practical purposes cross the placental barrier. Either autogenous maternal red cells may be labeled or banked type O, Rh-negative cells, prepared daily, may be used. The dosage varies from 10 to 20 μCi intravenously.

Kidney Scanning

Kidney scanning is clinically useful for detecting abnormalities in the size, shape, and position of the kidney. Some of the problems that occur in the kidney radiology such as overlying gaseous shadows, overlapping organs, and confusion with other structures are avoided.

Iodine 131 Labeled Compounds (S-12)

Renal scanning has been attempted with ^{131}I iodohippurate, but this agent is very rapidly excreted in the urine and does not satisfactorily outline the renal parenchyma. This difficulty is lessened by using a constant infusion of Hippuran intravenously during the time of scanning. Satisfactory renal scans can be obtained with several of the ^{131}I labeled renal contrast media.

Mercury 197, Mercury 203 Labeled Mercurials (S-13, S-17)

Neohydrin (Chlormerodrin) labeled with ^{203}Hg or ^{197}Hg are used for kidney scanning. The radioisotope ^{197}Hg has many characteristics that are ideal for external scintillation counting and scanning. It emits a gamma photon of 77 kev, and a characteristic x-ray of 69 kev. Because of its short physical half-life of 2.7 days, and lack of beta emission, the kidney and total body doses are reduced from those of a comparable amount of ^{203}Hg.

Three hundred μCi of ^{197}Hg chlormerodrin is injected intravenously 1 hour before scanning. Only a single injection is required because passage of radioactivity through the kidney is slow enough to outline the kidney for several hours. Chlormerodrin labeled with ^{197}Hg or ^{203}Hg is very sensitive in the detection of viable renal tissue, since this compound is concentrated in the renal tubular cells. Maximum concentration occurs in the kidney in 1 to 6 hours following injection, and visualization of the kidney is possible even in moderately uremic patients. With depressed renal function, increased hepatic uptake is noted.

Brain Scanning

In the case of mass brain lesions, the diagnostic problem consists of three parts: detection of the presence of the lesion; characterization of its size, shape, and position; and finally, identification of its nature. There is as yet no compound that is concentrated in brain (or other) tumer tissue as a result of metabolic activity such as the accumulation of iodine in the thyroid. Radiopharmaceuticals used for brain scanning are characterized by the fact that normal brain tissue is either relatively or completely impermeable to their passage from the blood. In contrast, brain tumors and most other mass lesions of the brain are much more permeable than normal brain, the degree of permeability varying with the type of lesion and the radiopharmaceutical.

Brain scanning agents may be classified on the basis of the biological properties of the materials as protein-bound substances, intracellular substances, and ionic extracellular substances. Classification may also be based on the radiation properties of the radioisotope. At the present time ^{99m}Tc pertechnetate, an ionic substance, and ^{203}Hg or ^{197}Hg chlormerodrin, a protein-bound substance, are widely employed in brain scanning procedures.

Technetium 99m Pertechnetate (S-1)

Technetium 99m pertechnetate is obtained from a molybdenum-99 generator, which consists of a shielded aluminum oxide column (the "cow") from which the pertechnetate can be eluted ("milked") daily. The usual dosage is 10 mCi, which is given intravenously 1 hour before the scanning. There is no beta particle and the energy of the gamma ray, 140 kev, is excellent for scanning. (An additional advantage is the short half-life of 6 hours.) The high dose gives high counting rates, and the scans can be completed in much shorter times than with some other agents.

Mercury 197 or Mercury 203 Labeled Mercurials (S-22, S-18)

Mercurials have found extremely wide application first when labeled with ^{203}Hg and later with ^{197}Hg. Most of the recent work has been done with ^{197}Hg labeled material because of the reduced dose to the kidneys. The half-life of ^{203}Hg is 47 days compared with 2.7 days for ^{197}Hg. In addition the latter has no beta particle, further reducing the total body and renal dose where the material, once fixed, practically remains for the physical decay period.

Liver Scanning

Radiopharmaceuticals used in liver scanning fall into two major categories: those taken up by the polygonal cells and those phagocytized by the Kupffer cells of the reticuloendothelial system. Agents taken up by the polygonal cells, such as rose bengal, are excreted into the biliary tree. The concentration of these agents in the liver changes during the time the liver is being scanned. Excretion into the intestine via the biliary tract may result in confusing abdominal activity. However these agents provide a means of demonstrating biliary obstruction. With some exceptions, phagocytized particles remain in the Kupffer cells of the liver almost indefinitely. Consequently, short lived radionuclides must be used to reduce radiation dose. In addition to the liver, other organs containing phagocytic cells, notably the spleen, accumulate particles and may be visualized by scanning.

Liver scanning is a simple technique without danger or discomfort to the patient. It has proved useful in the differential diagnosis of right upper quadrant pain and abdominal masses, in the detection of malposition and displacement of the liver, in the detection of metastatic disease, in the differentiation of obstructive from parenchymal causes of jaundice, in distinguishing focal from diffuse parenchymal disease, and as a means of following hepatic parenchymal abnormalities during the course of treatment.

Iodine 131 Rose Bengal (S-11)

The usual dosage varies from 1 to 3 μCi per kilogram of body weight administered intravenously. Scanning is begun about 10 minutes later, beginning at lower liver margin and proceeding upward to avoid the heavy concentration that occurs in the gallbladder and to avoid confusion by the material that enters the intestinal tract.

Gold 198 Colloid (S-15)

This material is supplied with a particle size varying from 0.005 to 0.05 microns with an average size of 0.039 microns. The usual dosage is 200 to 300 μCi but as little as 1 μCi/kg body weight may be used. Scanning may begin as soon as 10 minutes after injection but can be delayed for 24 hours or longer. The irradiation received by the liver from the usual dosage of ^{198}Au is of the order of 10 rads, while that from rose bengal is not more than 10 percent of that.

Technetium 99m Colloid (S-2)

Two millicuries of ^{99m}Tc-sulfur colloid is given intravenously 5 to 30 minutes before the scanning is begun. The dose to the liver is about 0.4 rads/mCi. It is important to obtain a lateral view as a routine procedure since it may reveal lesions that are not seen in the frontal view.

Bone Scanning--Strontium 85 or Strontium 87m Nitrate or Chloride (S-6, S-7)

Strontium, which is metabolized by bone in a manner similar to calcium, accumulates in areas of tumor-laden bone in greater concentration than in normal bone. This can be demonstrated by the radioactivity scanning technique.

A dosage of 100 to 200 μCi ^{85}Sr as inorganic strontium nitrate is given intravenously at least 48 to 72 hours before the scan. A somewhat more satisfactory dose of 2 mCi of ^{87m}Sr can be used. In this case the scan is performed 2 to 4 hours after administration.

Appendix G

SAMPLE SELECTION

Population Sampled

The Phase II sample was designed to obtain information on 23 different radiopharmaceutical procedures. These 23 procedures accounted for over 95 percent of the total number of patients reported in Phase I as receiving radiopharmaceuticals for diagnostic purposes. The list of physicians sampled was obtained from those respondents to the Phase I survey who reported doing any of the 23 procedures of interest in 1966. Physicians were grouped into two lists of identification numbers: (1) those physicians who reported doing any of the selected function procedures; and (2) those physicians who reported doing any of the selected scanning procedures.

Sampling Criteria

The sampling plan was designed to make the probability of a physician being sampled for a procedure depend on the number of patients for that procedure. Each physician was to receive a different questionnaire for each procedure for which he was sampled. To minimize the number of nonrespondents and also to minimize the time that the physicians took to respond, it was desired to limit the number of procedures sampled per physician to no more than 1 or 2 questionnaires per physician. To increase the response accuracy, it was also desired to minimize the number of physicians who receive more than one questionnaire for the same radionuclide. It was desired to obtain a sample of at least 50 physicians for each procedure.

Sampling Method

Four of the 23 procedures (F-3, S-2, S-7, and S-25) had fewer than 60 reported Phase I users and, hence, the practitioners of these procedures are included in the sample on a 100 percent basis. Approximately 50 physicians were selected from each of the remaining 19 procedures by a method that gives higher probability of being selected to those physicians who had higher usage of the procedure.

A list of physicians versus number of patients was made for each procedure. Within each of the procedures the physicians were then ranked in decreasing order on their number of patients. In order to facilitate stratification within procedures,* the following cumulative sum was calculated:

$$S_j = S_{j-1} + \sqrt{f_j}\,\sqrt{R_j}$$

where:

$j = 1, 2, \ldots, n$ each number representing a different group of physicians with the same number of patients. (The first group contains the physicians with the largest number of patients and the n^{th} group contains the physicians with the smallest number of patients.)

f_j represents the number of physicians in the j^{th} group.

R_j represents the range of patients in the j^{th} group.

[It was calculated by

$$R_j = \frac{P_{j-1} - P_{j+1}}{2}$$

where P_j represents the number of patients in the j^{th} group.]

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* According to the method of T. Dalenius and J. L. Hodges, Jr., Minimum Variance Stratification, Journal of the American Statistical Association, Vol. 54 (1959), pp 88-101.

The cumulative sum S_i was then divided into nine or ten uniform groups (strata). The strata with the larger number of patients contained fewer physicians than the strata with the fewer number of patients. The initial stratum was included in the sample with probability one because of the large number of patients the physicians in that stratum treated with the procedure. According to the optimum stratification procedure, once the strata are so defined, a good approximation to optimality of allocation of sample is achieved by randomly selecting equal numbers of elements from the remaining eight or nine strata. At this point no provision had been made to limit the number of procedures for which a physician was sampled. Since the percent of those who respond to a survey questionnaire is partly dependent on the number of questions asked, it was desirable to minimize the number of procedures sampled per physician. To accomplish this, a method of substitution was adopted that replaced procedures for each physician for whom more than two procedures had been selected. The substitute physician was randomly selected from the same stratum for that procedure as the physician originally chosen; i.e., a physician who had exactly the same probability of being selected for that procedure. When this substitution procedure was completed it was found that there remained in the sample eight physicians to be sampled for more than three procedures. Replacements could not be found for these physicians because of the four procedures sampled 100 percent and the one stratum for each of the other 19 procedures that was sampled 100 percent. It was decided for purposes of sample efficiency to leave these eight physicians in the sample and make a special effort to get them to respond.

After this adjustment had been made the client suggested that an effort be made to minimize the number of physicians who receive more than one questionnaire for the same radionuclide. The reason for this request was that a physician is likely to have the same response for a radionuclide independent of procedure. Hence, the same physician replacement technique was again used. A few such physicians did remain in the sample, however, since it was not always possible to find replacement physicians. It was felt that the advantage of leaving these physicians in the sample and thereby contributing to the precision of data summarization far outweighed the disadvantage of asking a physician to fill out two questionnaires with near identical information.

The results of the pretest program showed that a physician receiving one questionnaire was more inclined to respond promptly than a physician receiving two or three questionnaires. Since it is desirable to have a high prompt response that relieves the burden on the follow-on program, it was decided to reduce the number of physicians receiving two questionnaires. The same substitution technique was again used resulting in a minimum number of physicians receiving more than one questionnaire.

As a final check against possible tabulation errors of the Phase I response, the Phase II sample was checked against the physician's Phase I questionnaire. The purpose of this check was twofold: (1) to ensure that the physician actually does the procedure and had the listed number of patients, and (2) to check the physician's address against any corrections he may have indicated. A few errors were detected by this check and appropriate changes were made to the sample.

Sample Characteristics

An example of the sample stratification, which was developed for procedure S-11, according to the method described above is shown in Table G-1. The number of physicians who were sampled for various numbers of procedures is shown in Table G-2, while the number of questionnaires allocated for each procedure is shown in Table G-3.

Table G-1. Sample stratification for procedure S-11

Strata Number	Number of Physicians Sampled from Strata	Number of Physicians in Strata	Range of Number of Patients for Physicians in Strata
1	6	6	329-810
2	5	7	208-300
3	5	14	140-203
4	5	17	102-136
5	5	37	70-100
6	5	49	47- 69
7	5	51	30- 46
8	5	57	16- 29
9	5	103	6- 15
10	5	162	1- 5
Total	51	503	

Table G-2. Number of procedures sampled per physician

Number of Procedures Sampled	Number of Physicians	Total Number of Questionnaires
1	741	741
2	86	172
3	44	132
4	5	20
5	2	10
7	1	7
Total	879	1,082

Table G-3. Number of questionnaires allocated per procedure

Procedure Number	Number of Questionnaires
P-32 Blood Volume (F-3)	32
Cr-51 Blood Volume (F-4)	50
Co-57 Vitamin B-12 (F-7)	50
Co-60 Vitamin B-12 (F-8)	50
I-125/131 Blood Volume (F-9)	51
I-125/131 Fat Absorption (F-11)	50
I-125/131 Kidney Function (F-12)	50
I-131 Thyroid Function (F-13)	49
Tc-99m Brain Scan (S-1)	50
Tc-99m Liver Scan (S-2)	55
Sr-85 Bone Scan (S-6)	53
Sr-87 Bone Scan (S-7)	20
I-131 Thyroid Scan (S-8)	50
I-131 Lung Scan (S-9)	53
I-125/131 Placenta Scan (S-10)	50
I-131 Liver Scan (S-11)	51
I-131 Kidney Scan (S-12)	48
Hg-197 Kidney Scan (S-13)	52
Au-198 Liver Scan (S-15)	52
Hg-203 Kidney Scan (S-17)	51
Hg-203 Brain Scan (S-18)	50
Hg-197 Brain Scan (S-22)	52
Cr-51 Placenta Scan (S-25)	13
Total	1,082

Appendix H

COMPARISON OF RESPONSE FOR THE TWO MAILINGS OF QUESTIONNAIRES

Introduction

The Phase II Survey Questionnaires were mailed to the physician sample on March 10 through 13, 1969. A followup mailing was made on April 17 through 21, 1969 to those physicians who had not responded to the first mailing. This appendix contains comparisons of the responses for the two mailings.

Objective

The two mailings of Phase II Survey Questionnaires were made to improve the overall response. Comparisons were made of the two mailings in an effort to determine how well the respondents are representative of the nonrespondents. The nonrespondents were less than 15 percent of the overall sample and so they would have to be considerably different from the respondents to affect the results of the study.

Results

The number of questionnaires returned by the physicians responding to the two mailings is shown in Table H-1. The types of responses received from the first and second mailings are shown in Table H-2.

The percentage of nonusers of a given radiopharmaceutical in the respondents to the second mailing was over twice that of the first mailing respondents. This might account for the reluctance of these physicians to respond to the first mailing. Accordingly, it was assumed that the percentage of nonusers among the physicians who did not respond to either mailing was at least as high as the respondents to the

Table H-1. Response to the two mailings

Response Category	Response		
	First Mailing	Second Mailing	Total
Physicians	552 (62.7%)	197 (60.2%)	749 (85.2%)
Questionnaires	698 (64.5%)	226 (58.9%)	924 (85.4%)

Table H-2. Type of responses

Type of Response	Percent Response		
	First Mailing	Second Mailing	Total
Using same radionuclide			
Complete data	67.2	53.6	63.9
Incomplete data	0.6	1.8	0.9
Total	(67.8)	(55.4)	(64.8)
Changed radionuclide			
Complete data	20.2	18.1	19.7
Incomplete data	2.0	1.8	1.9
Total	(22.2)	(19.9)	(21.6)
Total reported users	(90.0)	(75.3)	(86.4)
No longer doing procedure	9.2	24.3	12.9
Other	0.8	0.4	0.7

second mailing. Such an assumption would mean that less than 80 percent (approximately 100) of the 130 nonresponding physicians were still doing the procedures for which they were sampled.

The total response by radiopharmaceutical procedure for the first and second mailings is given in Table H-3. After these total response data are adjusted for "changes in radionuclide" and "no longer doing" responses, the active practitioners of the second mailing response are less than 10 for most procedures. This means that there would be a lack of precision in detailed comparisons of responses to individual questions for the two mailings. Nevertheless such comparisons showed only small differences between the response of the active practitioners to the two mailings. Therefore, it was assumed that the detailed response that would be received from the nonrespondents would not differ significantly from that of the first and second mailings.

Table H-3. Total response for radiopharmaceutical procedures

Procedure	Number of Respondents*	
	First Mailing	Second Mailing
P-32 Blood Volume (F-3)	22	7
Cr-51 Blood Volume (F-4)	32	14
Co-57 Vitamin B-12 (F-7)	33	10
Co-60 Vitamin B-12 (F-8)	31	9
I-125/131 Blood Volume (F-9)	25	15
I-125/131 Fat Absorption (F-11)	37	8
I-125/131 Kidney Function (F-12)	42	6
I-131 Thyroid Function (F-13)	33	10
Tc-99m Brain Scan (S-1)	33	10
Tc-99m Liver Scan (S-2)	31	14
Sr-85 Bone Scan (S-6)	32	13
Sr-87m Bone Scan (S-7)	15	3
I-131 Thyroid Scan (S-8)	36	5
I-131 Lung Scan (S-9)	36	10
I-125/131 Placenta Scan (S-10)	32	14
I-131 Liver Scan (S-11)	35	11
I-131 Kidney Scan (S-12)	28	13
Hg-197 Kidney Scan (S-13)	34	11
Au-198 Liver Scan (S-15)	35	4
Hg-203 Kidney Scan (S-17)	25	14
Hg-203 Brain Scan (S-18)	29	11
Hg-197 Brain Scan (S-22)	32	11
Cr-51 Placenta Scan (S-25)	10	3

* See Table G-3 for the number of questionnaires allocated for each procedure

Appendix I

DATA NOT USED IN ANALYSIS

Because of radionuclide changes by many physicians in the procedures originally sampled, the data they reported could not be included with the data for the original procedure. The resultant sample size of complete data for detailed analysis is quite small for some of the procedures.

Rules were adopted for deciding if sufficient data were available for detailed analysis of a procedure. The sample size was considered adequate (1) if 20 or more complete sets of data were available for the procedure or (2) if the sample size of complete data sets for the procedure exceeded 80 percent of the number of questionnaires mailed. In those cases where the sample size was less than 80 percent of the number of questionnaires mailed, summaries were made only of the yes or no type questions if the sample size was in the range of 15 to 19 complete data sets. Using these criteria there was insufficient response for procedures F-3, S-7, S-18, S-22; and only yes or no type answers for procedures F-8 and S-12 were included in the analyses. The data not used for these procedures is given in the summary tables of this appendix.

Table I-1 shows the radionuclide changes which resulted in procedures not included in this study. Tables I-2 through I-9 correspond to summary tables presented in the RESULTS section of this report under the Radiopharmaceutical Handling and Patient Safeguards sections.

Table I-1. Radionuclide changes to procedures not included in study

Number of Responding Physicians Changing Radionuclide	Original Procedure	Radionuclide Now Being Used
1	I-131 Thyroid Scan (S-8)	I-125
2	I-131 Kidney Scan (S-12)	I-125
1	Hg-203 Brain Scan (S-18)	I-131
1	I-125/131 Kidney Function (F-12)	Hg-197
1	I-131 Thyroid Scan (S-8)	Tc-99m
4	I-131 Lung Scan (S-9)	Tc-99m
5	I-125/131 Placenta Scan (S-10)	Tc-99m
3	Cr-51 Placenta Scan (S-25)	Tc-99m
1	Hg-197 Kidney Scan (S-13)	Tc-99m
1	I-131 Lung Scan (S-9)	In-113m
1	Sr-85 Bone Scan (S-6)	F-18
1	I-125/131 Fat Absorption (F-11)	H-3

Table I-2. Place of practice

Procedure	Percent of Physicians Doing Procedure	
	Hospital Practice	Individual Office Practice
P-32 Blood Volume (F-3)	100	--
Sr-87m Bone Scan (S-7)	100	--
Hg-203 Brain Scan (S-18)	100	--
Hg-197 Brain Scan (S-22)	56.4	43.6

Table I-3. Radiopharmaceutical purchasing practices by procedure

Procedure	Percent of Physicians Doing Procedure			
	Unit-Dose Procurement	Multi-Dose Procurement	Generator Procurement	Unit-Dose and Multi-Dose Procurement
P-32 Blood Volume (F-3)	--	50.0	--	50.0
Sr-87m Bone Scan (S-7)	20.0	--	80.0	--
Hg-203 Brain Scan (S-18)	--	100	--	--
Hg-197 Brain Scan (S-22)	--	100	--	--

Table I-4. Testing of as-received radiopharmaceutical, by procedure

Procedure	Percent of Physicians Doing Procedure			
	No Tests	Yes Tests	Activity Assay	Purity and Activity
P-32 Blood Volume (F-3)	50.0	50.0	--	50.0
Co-60 Vitamin B-12 (F-8)	67.8	32.2	30.3	1.9
Sr-87m Bone Scan (S-7)	20.0	80.0	20.0	60.0
I-131 Kidney Scan (S-12)	88.3	11.7	8.3	3.4
Hg-203 Brain Scan (S-18)	59.2	40.8	25.3	15.5
Hg-197 Brain Scan (S-22)	77.2	22.8	5.0	17.8

Table I-5. Modification of radiopharmaceuticals

Procedure	Percent of Physicians Doing Procedure			
	No Modification	Yes Modification	Dilution	Tagging
Sr-87m Bone Scan (S-7)	60.0	40.0	20.0	20.0
I-131 Kidney Scan (S-12)	93.1	6.9	6.9	--
Hg-203 Brain Scan (S-18)	100	--	--	--
Hg-197 Brain Scan (S-22)	100	--	--	--

Table I-6. Testing of modified radiopharmaceutical

Procedure	Percent of Physicians Doing Procedure with Modified Radiopharmaceutical						
	No Tests	Yes Tests	Isotopic Purity	Activity Assay	Bound vs. Unbound Activity	pH	Pyrogen
Sr-87m Bone Scan (S-7)	--	100	50.0	100	50.0	50.0	50.0
I-131 Kidney Scan (S-12)	100	--	--	--	--	--	--

Table I-7. Blocking agent practices

Procedure	Percent of Physicians Doing Procedure				
	No Blocking	Yes Blocking	Blocking Agents Utilized		
			Iodides	Mercurial Diuretics	Vitamin B-12
P-32 Blood Volume (F-3)	50.0	50.0	50.0	--	--
Co-60 Vitamin B-12 (F-8)	82.7	17.3	--	--	17.3
Sr-87m Bone Scan (S-7)	100	--	--	--	--
I-131 Kidney Scan (S-12)	55.9	44.1	44.1	--	--
Hg-203 Brain Scan (S-18)	23.3	76.7	--	76.7	--
Hg-197 Brain Scan (S-22)	95.0	5.0	--	5.0	--

Table I-8. Administered radiopharmaceutical dosages

Procedure	Number of Physicians Responding	Administered Activity per Patient, μCi		
		Average of All Practitioners	Range of Values Reported by Sample of Practitioners	
			Minimum	Maximum
P-32 Blood Volume (F-3)	2	40.00	5.0	75.0
Co-60 Vitamin B-12 (F-8)	18	0.47	0.1	0.8
Sr-87m Bone Scan (S-7)	5	1,420.00	100.0	3,000.0
I-131 Kidney Scan (S-12)	15	151.07	18.0	300.0
Hg-203 Brain Scan (S-18)	6	679.34	550.0	750.0
Hg-197 Brain Scan (S-22)	8	769.31	100.0	1,200.0

Table I-9. Accelerated elimination practices

Procedure	Percent of Physicians Doing Procedure	
	Accelerated Elimination	
	No	Yes
P-32 Blood Volume (F-3)	100	--
Co-60 Vitamin B-12 (F-8)	86	14
Sr-87m Bone Scan (S-7)	100	--
I-131 Kidney Scan (S-12)	100	--
Hg-203 Brain Scan (S-18)	100	--
Hg-197 Brain Scan (S-22)	87	13